ESSAYS IN FINANCIAL ECONOMICS

BY

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This work is dedicated to my family.

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Despite a strong intuitive notion that macroeconomic conditions should influence equity values, few studies have been able to establish this relationship empirically. Previous research has used cash-market prices for equity indices, but perhaps options on those indices convey more information about how markets evaluate macroeconomic announcements. The implied volatility of index options can also provide independent evidence whether specific macro announcements affect the volatility of equity returns. Specifically, the implied volatility should fall following an important macroeconomic announcement, which reduces the uncertainty associated with future equity values. In this study, I examine the impact of a broad set of macroeconomic announcements on equity index options, in search of priced factors. In addition to the options' returns, I evaluate changes in their conditional and implied volatility around macro announcements. The data set includes nineteen macro announcement series and daily option prices over the period 1983-1999 and implied volatility for the period 1991-2002. I find that Balance of Trade, CPI, PPI, Employment, Housing Starts, Money Supply, and Retail Sales are

associated with higher conditional volatility of index option returns and that the same series cause a significant drop in the implied volatility of the index options.

It is also a well-known fact that on-the-run Treasury securities (i.e., most recently issued Treasury securities) trade at higher prices relative to off-the-run Treasury securities (i.e., securities issued at previous auctions with nearly identical terms to maturity). It is also well known that the spread in the yield of these securities converges to zero towards the next issuance date, i.e., when the current on-the-run issue becomes just-off-the-run issue and there is a new on-the-run issue traded in the market. This study investigates this discriminatory pricing and constructs some stylized facts about the spread between the yields of on-the-run and off-the-run Treasury securities by focusing on the possible factors and their effects on the spread between the Treasury securities. A new approach allowed this study to assemble the stylized facts both for the majority of the Treasury securities and for a time period going back to the mid 1970's.

CHAPTER 1
IMPACT OF MACROECONOMIC ANNOUNCEMENTS ON INDEX OPTIONS

Introduction

Despite the strong intuitive notion that macroeconomic conditions should influence equity values, it has been a challenge for academics to establish the relationship between macroeconomic information releases (announcements) and equity values. While numerous earlier studies have tried to establish the relationship (e.g., Chen, Roll, and Ross [1986], Fama [1981], Geske and Roll [1983], and Pearce and Roley [1985]), only inflation and monetary growth have been consistently identified as candidates for priced factors among the macroeconomic variables studied. In addition, some more recent studies (e.g., Chan, Karceski, and Lakonishok [1998]) totally reject the hypothesis that macroeconomic variables behave like factors for pricing equities.

However, previous studies mostly focused on the direct impact of the macroeconomic variables on the first moment of equity returns, ignoring the possibility that the relationship might be time-varying. Thus, the second moment should also be included when examining the effects of macroeconomic variables on equity returns. Bomfim (2003) presents evidence for the effect of public disclosure of monetary policy decisions on the conditional volatility of the stock market returns, and shows the changes around monetary policy announcement dates.

A recent provocatively titled study by Flannery and Protopapadakis [2000] (hereafter F&P) utilizes a GARCH model estimation that enables them to explore the effects of seventeen macroeconomic announcement series on both equity returns and their conditional volatility. They identify three nominal variables (the CPI, the PPI, and a monetary aggregate – M1 or M2) and three real variables (the Employment, the Balance of Trade, and Housing Starts) as candidates for factors affecting equity returns. In their study, only monetary growth affects both the realized equity returns and their conditional volatility, only nominal variables have an influence on equity returns, and only real variables have an effect on conditional volatility.

All of the above-mentioned research uses daily cash-market prices for equity indices. In this study, I examine the impact of a very broad set of macroeconomic announcements on equity index options. I utilize a GARCH model estimation to evaluate both the option returns' and their conditional volatility's variation with the macroeconomic announcements. In the second part of the analysis, I explore the effects of the macroeconomic announcements on the implied volatility of equity index options. The results of this study confirm that the effect captured by the GARCH model estimation for conditional volatility is not due to the misspecification of the utilized model.

Castanias (1979) analyzes the impact of macroeconomic information on the volatility of the daily market factor, suggesting that mis-specifying the temporal variations would bias coefficient estimates while looking for priced factors.

Patell and Wolfson [1979 and 1981] investigate the impact of earnings disclosures on the implied volatility of equity options. Cornell [1978], French and Frasier [1986],

Bailey [1988], French, Swidler, and Trapani [1994], Bonser-Neal and Tanner [1994], and Ederington and Lee [1996] investigate the behavior of foreign exchange and interest rate options' implied volatility around announcements. Bonser-Neal and Tanner [1994], and Ederington and Lee [1996] report evidence of a drop in the implied volatility following scheduled announcements. In addition, studies like Choi and Wohar [1992], Day and Lewis [1988, 1992], Jorion [1995], and Poteshman [2000] find that the option prices and implied volatility have some ability to predict actual volatility. Although Canina and Figlewski [1993] report that implied volatility has virtually no correlation with future return volatility and does not incorporate information contained in recent observed volatility, Christensen and Prabhala [1998] find that implied volatility outperforms past volatility in forecasting future volatility and even subsumes the information content of past volatility in some of their specifications. They attribute this difference from previous studies to the longer time series and nonoverlapping data they utilize in their study. Ederington and Guan [2002] also present evidence that implied volatility of S&P 500 options can indeed be used to measure the index's expected volatility. Hence, this study evaluates the effect of macroeconomic announcements on the implied volatility of the options.

It is expected that the implied volatility will drop after unusually valuable information releases into the market, because some uncertainty over the remaining life of the option is resolved by the new information and implied volatility is the average over the remaining life of the option. To see this phenomenon, imagine an option with T days to maturity. Tomorrow, there will be a macroeconomic announcement that may affect the underlying asset's value quite substantially. After tomorrow, however, no major

announcements are expected and so each day's asset volatility will be lower. At the close of business today, the average volatility for the underlying asset over the remaining T days of the option will be

$$\bar{\sigma} = \frac{1}{T}(K\sigma^2 + (T-1)\sigma^2) \qquad \text{(i)}$$

where σ^2 = the underlying asset's volatility on a day with no announcements, K = the ratio ($K \geq 1$) of the announcement day's return volatility to a non-announcement day's return volatility. As the announcement day passes, the mean remaining volatility in equation (i) falls if K>1.

This study's contribution is to confirm that macroeconomic variables with significant effects on the conditional volatility of the option returns (in GARCH model estimation) cause a significant drop in the implied volatility on their announcement dates. Hence, by examining the equity index options instead of the index cash prices, this analysis fills the gap between analyses trying to establish a relationship between equity values and macroeconomic conditions, and studies examining option markets to explore how they evaluate macroeconomic information releases. I find evidence that the macroeconomic variables that have significant effects on option returns and their conditional volatilities are also associated with significant drops in options' implied volatility; i.e., macroeconomic variables chosen as candidates for priced factors resolve some uncertainty over the remaining life of the corresponding option as well.

Section 2 of this chapter describes the data, section 3 examines the impact of macroeconomic announcements on equity option returns and their conditional volatility, and section 4 focuses on the effects of announcements on the options' implied volatility. Finally, section 5 follows with the conclusion.

Data

The macroeconomic announcement data set used in this study is probably the broadest data set in the literature. The data consist of nineteen macroeconomic announcement series for the period of January 1983–December 1999. Seventeen macroeconomic announcement series for the 1983-1996 period was kindly supplied by Mark Flannery and Aris Protopapadakis. The extension of the data for the 1997-1999 period, the additional series of the Durable Goods Order, and the Consumer Credit Expectations which was missing in F&P were purchased from Haver Analytics, which supplied MMS (a subsidiary of Standard and Poors) data for the above mentioned macroeconomic series. The data include the survey median (collected weekly by MMS from money-market economists and used as the expected value of the macroeconomic announcement), the actual announced value, and the corresponding dates. In addition, FOMC meeting dates and press release information were obtained from the Minneapolis Fed's website. Announcement dates series for all variables were also updated until the end of year 2002 from Haver Analytics to extend the period for the implied volatility analysis. Table 1-1 has the complete list of macroeconomic announcements with their mnemonic abbreviations, release times and availability.

All announcements occur monthly, with the exception of weekly M1. GDP is also somewhat special, in that GDP is a quarterly number. However, the Bureau of Economic Analysis makes three monthly announcements for the corresponding quarter. Starting with the fourth quarter of 1991, the Bureau of Economic Analysis announces the real GDP instead of the real GNP.

Most announcements are made early in the day, except for the Monetary Growth figures and, until October 1995, the Consumer Credit announcements. Therefore, these three series were aligned with the following day's close-to-close return for the period they were announced after the market's close.

While most of the announcement data is reported in percentage changes, Home Sales, Housing Starts, Employment, Money Supply, and Balance of Trade are reported in units and dollar terms. For these series F&P uses the nation's housing stock, total non-farm employment, M1 & M2 stocks, and sum of seasonally adjusted imports and exports, respectively, as deflators to convert them into growth series, and I adopt their methodology for creating the growth series I use in this study.

Panel A in Table 1-2 reports summary statistics about the number and the distribution of announcements, whereas Panel B has the number of announcements for individual macroeconomic series. There is at least one announcement on 2,546 days in the sample, which is 57.75% of the 4,409 total trading days. The original number of trading days was 4,420 from which 11 trading days for the market crashes in October 1987 and October 1989 were excluded to avoid possible outlier effects. The number of announcements for individual series is around 200, except for the weekly M1 series, which has 812 announcements. Panel A also reports the number of days with 1, 2, 3, 4, and 5 announcements.

Options data were purchased from CME. The options analyzed in this study are S&P 500 calls and puts between February 1983 and December 1999. Throughout the study, I use the daily closing option prices and implied volatility. In addition, the data for implied volatility are extended to December 2002.

Impact of Macroeconomic Announcements on Equity Option Returns

This section of the study focuses on the impact of macroeconomic announcements on the equity option returns, in search of candidates for priced factors. First, I show evidence that the mean daily option returns on announcement days is different from the mean of the returns on no announcement days. Second, the impact of the announcements on the option returns' volatility is visited. And finally, the GARCH model is presented to demonstrate the impact of individual announcements on the option returns and their conditional volatility.

Table 1-3 compares the means and medians of daily option returns on days with and without announcements. At the beginning of each week in the sample period, two nearest-the-money options (calls and puts) with shortest maturities and existing trading throughout the week are selected. Daily returns are calculated by taking the average of $\ln(C_t/C_{t-1})$ for the selected calls, where C_t is the closing price for the call option on day t (similarly, for put options, in Panel B, where P_t is the closing price for the put option on day t). Using two nearest-the-money call and put options (CME method) as described in Ederington and Guan [2002] also minimizes the effect of the so-called "volatility smile" because the effects of the smile get more severe the further away the strike price is from the spot price. Panel A shows the results of the significance tests for call options. Both means are significantly different from zero and each other at the 1% significance level. A Kruskal-Wallis test indicates that the medians are significantly different as well. Similar results for put options are shown in Panel B.

The last two columns in Table 1-2 include the standard deviations for daily call and put option returns for the sample period. Panel A shows that for both call and put

returns, standard deviation is more than twice as large on days with at least one announcement than the standard deviation on days with no announcement (F-stat.= 4.46 for calls, for H_0: $STD_{ann}=STD_{noann}$; F-stat.=5.43 for puts, for H_0:$STD_{ann}=STD_{noann}$, both significant at 1% level). Standard deviations of both call and put option returns are highest during the days with two announcements. (Visually observing the data revealed that the two announcements that stand out are generally M1 and M2.)

Table 1-2, Panel B, reports the standard deviations of daily call and put option returns during the announcement days of individual macroeconomic series. Balance of Trade, CPI, Employment, Housing Starts, Industrial Production, M1, M2, PPI, and Retail Sales clearly stand out with high standard deviations. Later in the paper I will refer to these results again.

Garch model. Like F&P, I also utilize a GARCH (1,1) model to estimate the effect of the announcement surprises on the returns, while incorporating the impact of the existence of announcements on the conditional volatility (Bollerslev, Chou, and Kroner [1992]).

(1a) $$R_t = E_{t-1}(R_t) + \sum_{n=1}^{18} \beta_n \left[A_{nt} - E_{t-1}(A_{nt})\right] + u_t\,,$$

(1b) $$E_{t-1}(R_t) = R_0 + \Omega TBill_{t-1} + \Pi\Pi_{t-1} + \sum_{w=1}^{4} \omega_w WDDUM_{wt} + \sum_{k=1}^{6} \lambda_k JDUM_{kt}\,,$$

(1c) $u_t \equiv h_t \varepsilon_t$, where $\varepsilon_t \sim N(0,1)$ and i.i.d.,

(1d) $$h_t^2 = \left\{h_0 + Ph_{t-1}^2 + \Phi u_{t-1}^2 + \Gamma TBill_{t-1}\right\} * \operatorname{Exp}\left\{\sum_{w=1}^{4} \alpha_w WDDUM_{wt} + \alpha_r PREHDUM_t + \alpha_s POSTHDUM_t + \sum_{n=1}^{19} f_n AD_{nt}\right\}\,,$$

where $R_t = \ln(C_t/C_{t-1})$ for call options (P for put options),

A_{nt} is the announced value of the n^{th} macroeconomic variable on day t,

I_{t-1} is the previous day's S&P 500 Index return (from CRSP),

$Tbill_{t-1}$ is the lagged (one day) 3-month T-Bill rate (from CRSP Treasuries Daily Database).

Equation (1a) is the "option returns equation." A_{nt} is the announced value of the n^{th} macroeconomic variable on day t, and $[A_{nt}-E_{t-1}(A_{nt})]$ captures the announcement surprise. Equation (1b) is the "expected option returns equation," where I_{t-1} and $Tbill_{t-1}$ are used as conditioning variables (Fama [1990], the results were not sensitive to the inclusion of junk bond premium and term premium as additional conditioning variables; hence, they are not reported in the tables). Equity returns and volatility have been known to have a weekly pattern (French and Roll [1986]). Therefore, WDDUM (four 0-1 weekday dummies for Monday, Tuesday, Thursday, and Friday) are added to the equation (1d) to control for the week-of-the-day effect. The well-known "January Effect" (Keim [1983]) is captured by JDUM (six 0-1 dummy variables): one dummy variable for the days December 28-30, another dummy variable for the last trading day of the year, and four more dummy variables for the first four weeks of January. Finally, equation (1d) is the "conditional volatility equation," which captures the impact of an announcement's existence on the conditional volatility of errors from equation (1a). PREHDUM is a dummy variable for a day preceding a holiday; POSTHDUM is similarly for a day following a holiday. AD_{nt} are dummy variables for the macroeconomic announcements. Notice that we have sixteen dummy variables for eighteen macroeconomic variables

(excluding FOMC meetings) because Employment and Unemployment are announced simultaneously and so are Personal Income and Personal Consumption. The additional three dummy variables in equation (1d) include one dummy variable for last days of FOMC meetings before 1994, a second variable for last days of FOMC meetings after 1994, and a third one for post 1994 FOMC meeting dates when there was a press release after the meeting. FOMC started to issue press releases only after the beginning of 1994. The addition of these dummy variables to the analysis is to capture any effect of these meetings or press releases on the conditional volatility of returns.

Table 1-4 reports the estimation results for call options using the GARCH model described by equations (1a)-(1d) for January 1983-December 1999. CPI, M1, M2, and PPI have significant coefficient estimates in the option returns equation at the 1% significance level, confirming the findings of F&P. In addition, BOT and RETSL have significant coefficient estimates at the 5% level. Among the conditional volatility equation coefficients, BOT, EMP, GDP, M1, M2, PPI, and RETSL have significant coefficients. Since the announcement dummy variables in the equation (1d) are in Exp{} form, a reported coefficient greater than unity indicates that a higher conditional volatility is associated with the corresponding macroeconomic announcement. However, the t-statistics test whether the coefficients themselves are different from zero. Surprisingly, GDP has a significant reported coefficient smaller than unity, implying a lower conditional volatility on GDP announcement days than the conditional volatility on a day with no announcement. The biggest effect on conditional volatility comes from EMP (1.333) (again confirming F&P). Both ARMA parameters (P and Φ) are also significant at the 1% level.

The results for the put options reported in Table 1-5 mirror the results in Table 1-4. For put options, option returns equation estimates again confirm the findings of F&P: CPI, PPI, and Money Supply are the most significant factor candidates. Notice that all coefficient estimates in the option returns equation for the put options change sign as put option prices are expected to move inversely with call option prices. ARMA parameters are significant again at the 1% level.

The results of the two GARCH estimations suggest that 7 macroeconomic variables can be candidates for risk factors in the equity options market: BOT, CPI, EMP, GDP, M1 (or M2), PPI, and RETSL.

A more important finding is in the conditional volatility equation results evaluating Table 1-4 and 1-5 together. Macroeconomic variables that have a significant coefficient estimate in the conditional volatility equation for either call or put options, or for both, make up the list of variables in Table 1-2, which were associated with higher standard deviation of option returns. That is, significant coefficient estimates for equation (1d) are not due to a misspecification of the model. Macroeconomic variables that cause an increase in the volatility by their announcements also increase the conditional volatility, implying that the relationships between macroeconomic variables and equity values are time-varying. I will revisit this argument at the end of the next section, where the analysis focuses on the impact of macroeconomic announcements on implied volatility.

Impact of Macroeconomic Announcements on Equity Options' Implied Volatility

Initially, implied volatility values are calculated utilizing the widely-used "Black-Scholes Option Pricing Formula" (CME also uses the same method to calculate implied volatilities). Daily implied volatility changes for the sample period are calculated by

comparing the equally-weighted average of implied volatilities for the two nearest-the-money call and the two nearest-the-money put options for consecutive days (Ederington and Guan [2002]). At the beginning of every week nearest-the-money option contracts are respecified and the implied volatility series is established accordingly.

Ederington and Guan [2002] compare different methods of averaging implied volatilities to decide which method provides a better measure for market's volatility expectation. Their study concludes that the CME method (averaging two nearest-the-money call and put options) yields the best results. Later in the study different methods of averaging implied volatilities, as well as a modified option pricing formula other than Black-Scholes, will be utilized to calculate implied volatilities as a robustness check of the results.

Beginning in 1991, CME provides the volatility implied by each option's price. To get a longer time period, I computed a daily implied volatility series from the Black-Scholes formula for the period 1983-2002. As mentioned above, implied volatilities are also calculated using a modified option pricing formula proposed by Savickas [2002], where the underlying asset price is assumed to follow a Weibull distribution as opposed to log-normal as in the Black-Scholes formula. Savickas [2002] also presents evidence that this simple option pricing formula eliminates the biases in the Black-Scholes method, and option prices produced by this formula generally lie within or close to the actual bid-ask spread for all strike prices when applied to S&P 500 options. Implied volatility analysis with different methodologies will be reported after the initial results obtained by the CME method utilizing the Black-Scholes formula.

If macroeconomic announcements convey valuable information to the market, then we should expect to see a significant drop in the implied volatility following their announcements because some uncertainty over the remaining life of the option is resolved by the new information and because implied volatility is the average over the remaining life of the option. The release of the new information will resolve at least part of the uncertainty associated with the future value of the underlying equity value. In this section of the study, I follow a similar methodology used by Ederington and Lee [1996] (E&L, hereafter) to explore the impact of macroeconomic announcements on the implied volatility S&P 500 options. E&L find that anticipated announcements that increase the volatility of these option returns cause a significant drop in their implied volatility. This fact enables us to investigate whether the risk factor candidates shown in the option returns framework have consistent effects on the option implied volatility as well.

The first row in Table 1-6 illustrates the comparison of the mean implied volatility changes for trading days with and without macroeconomic announcements. As hypothesized above, trading days without any announcements are associated with a positive mean implied volatility change, whereas the sign of the same average is negative for the days with announcements. The mean volatility changes are significantly different from zero and from each other, both at the 1% level. As in Table 1-3, the Kruskal-Wallis test (in row 4) is used to compare the two corresponding medians, and they too are significantly different from each other at the 1% level. Rows 5 and 6 show that the percentage of days with implied volatility drops are significantly different from 50% and each other for days with and without macroeconomic announcements.

Tables 1-7 and 1-8 repeat the comparisons in Table 1-6 separately for call and put option contracts. The results clearly demonstrate that the daily implied volatility changes of both call and put option contracts behave differently on days with macroeconomic announcements.

I now test whether the macroeconomic announcements that are associated with high volatility in Table 1-2 and conditional volatility in section 3, are also causing a significant drop in the implied volatilities. I estimate the following model:

$$\ln(\sigma_t / \sigma_{t-1}) = \beta_0 + \sum_{i=1}^{19} \beta_k AD_{kt} + u_{t,} \qquad (2)$$

where

$$u_t = \sum_{j=1}^{2} \alpha_j u_{t-j} + \varepsilon_t,$$

and $\epsilon_t \sim N(0,1)$ i.i.d.

The first column of Table 1-9 shows the results of estimating equation (2) using the call-put average of the daily implied volatility changes for the entire sample period. As expected, the coefficient of the intercept (no announcements, notice the AD variable represents the announcement dummies as in equation (1d), hence the intercept represents the days with all announcement dummies are equal to zero, i.e. no announcement days) is positive and significant at the 1% level. All of the significant coefficients and most of them overall have negative signs. This is consistent with the hypothesis that the macroeconomic announcements resolve some uncertainty and hence cause a drop in the implied volatility. But, the variables with significant coefficient estimates require special attention: BOT, CPI, EMP, M1, M2, and PPI, all are among the variables associated with high unconditional volatility in the initial analysis. The last three columns of Table 1-9

demonstrate the same relationship for different macro regimes. Macro regimes are defined using a similar method as in McQueen and Roley [1993]. Low, moderate, or high levels of monthly growth in industrial production determine the three macro regimes used in this part of the study.

Tables 1-10 and 11 present the results of the same regression separately for call and put options. The results are almost identical including the higher significance levels for the low growth period.

Tables 1-12, 1-13, and 1-14 repeat the analyses in Tables 1-6, 1-7, and 1-9 as robustness check of the initial results. Each Panel A in those tables reports the results utilizing a weighted average of implied volatilities of chosen options instead of the CME method. The weights are chosen such that the average strike price equals the underlying asset price (Ederington and Guan [2002]). Panel B of Tables 1-12, 1-13, and 1-14 report results with equally weighted averages of implied volatilities of all traded options. Finally, Panel C report the results with implied volatilities derived from the modified option pricing formula suggested by Savickas [2002]. The results of the robustness check confirm the initial findings.

Similarly, Table 1-15 repeats the regression analysis in Table 1-9 and reports the results for four different groups of implied volatilities. All methods identify the same group of announcement series as significant factors associated with drops in corresponding implied volatilities.

In addition, the first row of Table 1-16 demonstrates that the mean daily implied volatility changes are different from zero and each other during days with at least one significant announcement (significant variables are selected in accordance with the

results in Tables 1-9 through 1-11) than days with no announcement. The second and third rows of table 16 present similar results for call and put options separately.

Finally, Table 1-17 repeats the same analysis by comparing the mean daily implied volatility changes between days with at least one significant announcement and days with no significant announcement (but possibly with some announcement that did not show any significance in the previous regression analysis). Again, days with significant announcements observe drops in the implied volatility in all cases (average of call-put, or call and put separately).

Conclusion

This study explores the impact of macroeconomic announcements on the equity index options in search of candidates for priced factors. The results present evidence for the time-varying nature of the relationships between announcements and option returns, supporting the choice of a GARCH model to analyze both the effects on prices and the effects on the conditional volatility.

I find that seven macroeconomic announcement series (BOT, CPI, PPI, Money Supply, Housing Starts, Employment, and Retail Sales) are candidates for priced factors, which show evidence for significant effects on the option returns, conditional volatility (in GARCH model estimation) and option return volatility. By examining the equity index options instead of the index cash prices, this analysis fills the gap between analyses trying to establish a relationship between equity values and macroeconomic conditions, and studies examining option markets to explore how they evaluate macroeconomic information releases. I find evidence that six out of seven candidates discussed earlier (leaving only Retail Sales out) are also associated with significant drops in options' implied volatility; i.e., macroeconomic variables chosen as candidates for priced factors

resolve some uncertainty over the remaining life of the corresponding option as well. In addition, this result shows that the significant coefficient estimates in the GARCH model are not due to a mis-specification of the model. Macroeconomic variables that are associated with an increase in volatility by their announcements are also associated with a decrease in the implied volatility, implying that the relationships between equity values and macroeconomic variables are time-varying.

Table 1-1. Timing and Availability of Macroeconomic Announcements (1983-1999)[1]:

VARIABLE	Announcement Time	First Available Data for: Announcement Dates	First Available Data for: Expectations
Balance of Trade BOT[2]	2:30 PM through 11/29/83 9:30 AM - 12/29/83 8:30 AM – 1/27/84 on	January 1983	January 1983
Consumer Credit CCRDT	4:15 PM through 3/15/84 4:00 PM through 10/6/95 3:00 PM thereafter	January 1983	January 1983
Construction Spending CNSTR	10:00 AM throughout sample	January 1983	January 1983
Consumer Price Index CPI	8:30 AM throughout sample	January 1983	January 1983
Employment EMP[3]	8:30 AM throughout sample	January 1983	February 1985
Unemployment UNEMP[3]	8:30 AM throughout sample	January 1983	January 1983
Real GNP Real GDP GDP[4]	10:00 AM through 10/20/83 8:30 AM thereafter	January 1983	81-1Q to 91-3Q Since 91- 4Q
New Home Sales HSAL	10:00 AM throughout sample	January 1983	March 1988
Housing Starts HSTR	2:30 PM through 11/17/83 9:30 AM 12/20/83 8:30 AM – 1/18/84 on	January 1983	January 1983
Industrial Production INPRD	9:30 AM through 10/16/85 9:15 AM thereafter	January 1983	January 1983
Leading Indicators LIND	8:30 – 10:30 AM before 2/29/84, 8:30 AM thereafter	January 1983	January 1983
M1 (weekly)[5]	4:15 PM through 3/15/84 4:30 PM thereafter	January 1983	January 1983
M2 (monthly)[5]	4:15 PM through 3/15/84 4:30 PM thereafter	January 1983	January 1983
Personal Consump. PERC[3]	10:00 AM throughout sample	January 1983	July 1985
Personal Income PERI[3]	10:00 AM throughout sample	January 1983	January 1983
Producer Price Index PPI	8:30 AM throughout sample	January 1983	January 1983
Retail Sales RETSL	2:30 PM through 11/10/83 8:30 AM - 12/13/83 on	January 1983	January 1983
Durable Goods Orders DGOR	10:00 AM throughout sample	January 1983	January 1983
FOMC Meetings[6]	Shortly after noon <u>(to be checked for sample per.)</u>	January 1983	N/A

Table 1 (contd.): Notes on Macroeconomic Announcements

[1] Announcement dates for all variables are acquired until the end of year 2002 allowing the implied volatility analysis to be extended to the period 1983-2002.

[2] Balance of Merchandise Trade through October 1994, Balance of Goods and Services after November1994.

[3] EMP and UNEMP are announced simultaneously, as are PERI and PERC.

[4] Monthly announcements are made about the most recent calendar quarter's rate of GNP or GDP growth.

[5] One out of every for M1 announcements is made simultaneously with an M2 announcement.

[6] FOMC meeting dates are used to create dummy variables as described in the analysis. The dates were available throughout the sample period (1983-2002).

Table 1-2. Macroeconomic Announcements and Option Return Volatility (1983-1999)

Panel A: Announcement Status and Option Return Volatility

	Number of Trading Days	% of Trading Days	STD of Daily Call Returns[1]	STD of Daily Put Returns[1]
Number of Trading Days[2]	4,409	100.00	0.647	0.713
With No Announcements	1,863	42.25	0.394	0.406
With Announcements	2,546	57.75	0.832	0.946
1 Announcement	1,497	33.95	0.524	0.570
2 Announcements	727	16.49	1.353	1.624
3 Announcements	228	5.17	0.513	0.598
4 Announcements	37	0.84	0.514	0.669
5 Announcements	3	0.07	0.307	0.384

Panel B: Individual Announcements and Option Return Volatility

Variable	Number of Announcements	STD of Daily Call Returns[1]	STD of Daily Put Returns[1]
Balance of Trade	203	0.913	0.924
Consumer Credit	200	0.483	0.470
Construction Spending	197	0.312	0.429
Consumer Price Index	202	0.788	0.936
Employment and Unemployment[3]	200	0.879	0.931
Real GDP	201	0.301	0.312
New Home Sales	199	0.291	0.364
Housing Starts	203	0.770	0.902
Industrial Production	199	0.651	0.783
Leading Indicators	198	0.260	0.255
M1	812	1.288	1.562
M2	198	1.483	1.663
Personal Consumption and Pers.Inc.[3]	197	0.449	0.501
Producer Price Index	196	0.693	1.038
Retail Sales	196	0.607	1.079
Durable Goods Orders	197	0.224	0.236
FOMC	136	0.478	0.509
	3,934		

[1] The standard deviation of daily returns for the two nearest-the-money calls (puts) on the corresponding trading days.

[2] The original number of trading days was 4,420 from which we excluded 11 trading days for the market crashes in October 1987 and October 1989.

[3] Employment and Unemployment are announced simultaneously, as are Personal Consumption and Personal Income.

Table 1-3. Impact of Macroeconomic Announcements on Option Returns (1983-1999)

Panel A: Call Returns

	Trading Days with Announcements	Trading Days without Announcements
Mean of ln (C_t/C_{t-1})	0.061	0.043
t-stat. (H_0: mean = 0)	3.057**	2.913**
t-stat. (H_0: $mean_{ann} = mean_{noann}$)	3.712**	
Median of ln (C_t/C_{t-1})	0.058	0.041
Kruskal-Wallis stat. (H_0: $Med_{ann} = Med_{noann}$)	41.526**	

Panel B: Put Returns

	Trading Days with Announcements	Trading Days without Announcements
Mean of ln (P_t/P_{t-1})	0.009	-0.006
t-stat. (H_0: mean = 0)	1.993**	1.986*
t-stat. (H_0: $mean_{ann} = mean_{noann}$)	3.001**	
Median of ln(P_t/P_{t-1})	0.007	-0.003
Kruskal-Wallis stat. (H_0: $Med_{ann} = Med_{noann}$)	11.721**	

Statistics are calculated for ln (C_t/C_{t-1}) for call options and ln (P_t/P_{t-1}) for put options, where C and P are the average daily closing prices of the corresponding two nearest-the-money options. At the beginning of every week, two nearest-the-money options are reselected, and the returns are calculated accordingly for the following week. T-statistics calculated for the comparison of the means allow unequal variances, however a constant ratio of the variances for the periods with and without announcements is assumed to calculate the corresponding two-tailed t-statistics where the ratio is derived from the sample period 1983-1999. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-4. Impact of Individual Macroeconomic Announcements on CALL Returns and their Conditional Volatility (GARCH model estimation results for 1983-1999):

	Option Returns Equation (1a)	Conditional Vol. Equation (1d)		Expected Option Returns Eqn. (1b)
BOT	-0.032* (2.04)	1.327** (2.69)	**R_0**	0.026 (0.79)
CCRDT	0.008 (0.99)	1.041 (0.87)	**Ω**	0.009* (2.19)
CNSTR	0.021 (0.85)	0.911 (1.16)	**Π**	0.041** (2.71)
CPI	-0.038** (2.86)	1.113 (1.61)	**MONDUM**	-0.069** (3.27)
EMP	-0.011 (1.06)	1.341** (4.06)	**TUEDUM**	-0.081** (2.93)
UNEMP	0.003 (1.13)	Same ann. dummy as above	**THUDUM**	-0.048* (2.01)
GDP	0.018 (1.65)	0.827** (3.10)	**FRIDUM**	-0.057** (2.64)
HSAL	0.012 (0.98)	0.726 (1.81)	**DECDUM**	-0.021 (1.31)
HSTR	0.043 (1.28)	1.120 (1.63)	**YENDDUM**	-0.007 (0.93)
INPRD	0.016 (0.81)	0.893 (0.83)	**JWEEK1**	-0.007 (1.23)
LIND	0.037 (1.31)	0.952 (1.13)	**JWEEK2**	-0.014 (0.96)
M1	-0.081** (3.26)	1.452** (2.83)	**JWEEK3**	-0.016 (0.86)
M2	-0.053* (2.20)	1.386** (2.95)	**JWEEK4**	-0.015 (1.41)
PERC	0.006 (0.91)	0.971 (0.65)		
PERI	0.013 (1.32)	Same ann. dummy as above		
PPI	-0.063** (2.92)	1.240* (2.072)		
RETSL	0.027* (2.11)	1.365* (2.12)		
DGOR	0.026 (1.20)	0.954 (0.73)		
PRE'94 FOMC	--	0.328 (0.98)		
POST'94 FOMC	--	0.418 (1.712)		
POST'94 FOMC PRESS REL.	--	0.865* (2.04)		

Table 1-4 (contd.)

	Option Returns Equation (1a)	Conditional Volatility Equation (1d)
MONDUM	--	1.252** (3.48)
TUEDUM	--	1.096* (2.24)
THUDUM	--	1.114** (2.77)
FRIDUM	--	1.153* (2.05)
PREHDUM	--	0.314** (3.21)
POSTHDUM	--	1.376* (2.03)
Γ	--	0.037 (0.69)
P	--	0.689** (4.37)
Φ	--	0.098** (2.57)

(1a) $$R_t = E_{t-1}(R_t) + \sum_{n=1}^{18} \beta_n \left[A_{nt} - E_{t-1}(A_{nt})\right] + u_t ,$$

(1b) $$E_{t-1}(R_t) = R_0 + \Omega TBill_{t-1} + \Pi I_{t-1} + \sum_{w=1}^{4} \omega_w WDDUM_{wt} + \sum_{k=1}^{6} \lambda_k JDUM_{kt} ,$$

(1c) $u_t \equiv h_t \varepsilon_t$, where $\varepsilon_t \sim N(0,1)$ and i.i.d.,

(1d) $$h_t^2 = \left\{h_0 + Ph_{t-1}^2 + \Phi u_{t-1}^2 + \Gamma TBill_{t-1}\right\} * \\ \mathrm{Exp}\left\{\sum_{w=1}^{4} \alpha_w WDDUM_{wt} + \alpha_r PREHDUM_t + \alpha_s POSTHDUM_t + \sum_{n=1}^{19} f_n AD_{nt}\right\} ,$$

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.
See Table 1 for variable mnemonics and Section III for GARCH model description.

Table 1-5. Impact of Individual Macroeconomic Announcements on PUT Returns and their Conditional Volatility (GARCH model estimation results for 1983-1999):

	Option Returns Equation (1a)	**Conditional Vol. Equation (1d)**		**Expected Option Returns Eqn. (1b)**
BOT	0.023* (2.11)	1.427** (3.24)	R_0	-0.021 (1.49)
CCRDT	-0.027 (1.26)	1.265 (0.87)	Ω	0.013* (2.08)
CNSTR	-0.032 (1.56)	1.245 (1.32)	Π	-0.049** (3.37)
CPI	0.061** (3.28)	1.34* (2.07)	**MONDUM**	0.068** (3.31)
EMP	-0.003 (1.15)	1.789** (4.01)	**TUEDUM**	0.077** (2.98)
UNEMP	-0.003 (0.96)	Same ann. dummy as above	**THUDUM**	0.063* (2.21)
GDP	-0.034 (1.76)	0.976** (2.83)	**FRIDUM**	0.073* (2.11)
HSAL	-0.027 (1.62)	0.847 (1.62)	**DECDUM**	0.035 (1.77)
HSTR	-0.074 (1.42)	1.48* (2.10)	**YENDDUM**	0.027 (1.48)
INPRD	-0.027 (1.45)	1.027 (0.87)	**JWEEK1**	0.0180 (1.26)
LIND	-0.049 (1.42)	1.235 (1.48)	**JWEEK2**	0.022 (1.43)
M1	0.078** (3.51)	1.576** (3.11)	**JWEEK3**	0.041 (1.76)
M2	0.052* (2.03)	1.542** (3.04)	**JWEEK4**	0.032 (1.55)
PERC	-0.017 (1.42)	1.161 (1.19)		
PERI	-0.018 (1.17)	Same ann. dummy as above		
PPI	0.087** (3.12)	1.274 (1.743)		
RETSL	-0.053 (1.82)	1.316* (2.32)		
DGOR	-0.017 (1.57)	1.018 (1.33)		
PRE'94 FOMC	--	0.441 (1.06)		
POST'94 FOMC	--	0.524 (1.74)		
POST'94 FOMC PRESS REL.	--	0.974* (2.21)		

Table 1-5 (contd.)

	Option Returns Equation (1a)	**Conditional Volatility Equation (1d)**
MONDUM	--	0.771** (2.94)
TUEDUM	--	0.863** (2.81)
THUDUM	--	0.879** (3.21)
FRIDUM	--	0.927* (2.06)
PREHDUM	--	0.692** (2.83)
POSTHDUM	--	1.571** (3.27)
Γ	--	0.042 (0.73)
P	--	0.749** (2.95)
Φ	--	0.178** (2.72)

(1a) $$R_t = E_{t-1}(R_t) + \sum_{n=1}^{18} \beta_n \left[A_{nt} - E_{t-1}(A_{nt})\right] + u_t ,$$

(1b) $$E_{t-1}(R_t) = R_0 + \Omega TBill_{t-1} + \Pi\Pi_{t-1} + \sum_{w=1}^{4} \omega_w WDDUM_{wt} + \sum_{k=1}^{6} \lambda_k JDUM_{kt} ,$$

(1c) $u_t \equiv h_t \varepsilon_t$, where $\varepsilon_t \sim N(0,1)$ and i.i.d.,

(1d) $$h_t^2 = \left\{h_0 + Ph_{t-1}^2 + \Phi u_{t-1}^2 + \Gamma TBill_{t-1}\right\} * \mathrm{Exp}\left\{\sum_{w=1}^{4} \alpha_w WDDUM_{wt} + \alpha_r PREHDUM_t + \alpha_s POSTHDUM_t + \sum_{n=1}^{19} f_n AD_{nt}\right\} ,$$

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.
See Table 1 for variable mnemonics and Section III for GARCH model description.

Table 1-6. Impact of Macroeconomic Announcements on Implied Volatility (Call-Put Avg.)

		Trading Days with Announcements	**Trading Days without Announcements**
1	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0573 3.006**	0.027 2.716**
2	**t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)**	2.836**	
3	**Median of $\ln(\sigma_t/\sigma_{t-1})$**	-0.0617	0.032
4	**Kruskal-Wallis stat.** **(H_0: med_{ann} = med_{noann})**	31.962**	
5	**Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$** **z-stat. ($H_0$: percentage = 0.5)**	61.03% 3.96**	38.87% 3.88**
6	**χ^2-stat.** **(H_0: $percentage_{ann}$ = $percentage_{noann}$)**	22.371**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the implied volatility of the two nearest-the-money call and put options. At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-7. Impact of Macroeconomic Announcements on Implied Volatility (Call Options)

		Trading Days with Announcements	Trading Days without Announcements
1	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0551 2.918**	0.024 2.668**
2	**t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)**	2.839**	
3	**Median of $\ln(\sigma_t/\sigma_{t-1})$**	-0.0607	0.031
4	**Kruskal-Wallis stat.** **(H_0: med_{ann} = med_{noann})**	31.734**	
5	**Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})$<0** **z-stat. ($H_0$: percentage = 0.5)**	61.76% 3.98**	38.24% 3.92**
6	**χ^2-stat.** **(H_0: $percentage_{ann}$ = $percentage_{noann}$)**	21.991**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the implied volatility of the two nearest-the-money call options. At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-8. Impact of Macroeconomic Announcements on Implied Volatility (Put Options)

		Trading Days with Announcements	**Trading Days without Announcements**
1	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0595 3.019**	0.030 2.834**
2	**t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)**	2.922**	
3	**Median of $\ln(\sigma_t/\sigma_{t-1})$**	-0.0632	0.041
4	**Kruskal-Wallis stat.** **(H_0: med_{ann} = med_{noann})**	31.896**	
5	**Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$** **z-stat. ($H_0$: percentage = 0.5)**	61.27% 3.57**	38.73% 3.81**
6	**χ^2-stat.** **(H_0: $percentage_{ann}$ = $percentage_{noann}$)**	22.216**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the implied volatility of the two nearest-the-money put options. At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-9. Impact of Individual Macroeconomic Announcements on Implied Volatility (Regression Results for Full Sample (1983-2002) and Different Macro Regimes[1] using Call-Put Avg.):

Dummy Variables for Individual Announcements	Full Sample	Low Growth	Moderate Growth	High Growth
Intercept (no announcement)	0.0057*	0.0063*	0.0054*	0.0048*
	(2.24)	(2.17)	(2.23)	(2.06)
Balance of Trade	-0.0137*	-0.0142**	-0.0129*	-0.0122
	(1.99)	(2.60)	(2.18)	(1.92)
Consumer Credit	-0.0025	-0.0031	-0.0023	-0.0023
	(0.72)	(0.80)	(0.82)	(0.56)
Construction Spending	-0.0015	-0.0021	-0.0018	-0.0011
	(0.99)	(0.86)	(0.71)	(0.73)
Consumer Price Index	-0.0119**	-0.0130*	-0.0135*	-0.0126
	(2.96)	(2.43)	(1.94)	(1.88)
Employment	-0.0193**	-0.0189**	-0.0189**	-0.0182*
	(3.11)	(2.98)	(2.63)	(2.04)
Unemployment	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)
Real GDP	-0.0039	-0.0051	-0.0063	-0.0038
	(1.31)	(1.43)	(1.12)	(1.12)
New Home Sales	0.0018	-0.0006	0.0011	0.0011
	(1.16)	(0.47)	(0.68)	(0.73)
Housing Starts	-0.0131*	-0.0136**	-0.0168*	-0.0116*
	(2.19)	(2.92)	(2.09)	(2.03)
Industrial Production	-0.0042	-0.0047	-0.0048	-0.0063
	(1.52)	(1.43)	(0.82)	(1.16)
Leading Indicators	0.0011	-0.0030	0.0033	0.0036
	(0.69)	(0.78)	(0.85)	(0.52)
M1	-0.0141*	-0.0164**	-0.0156*	-0.0158
	(2.30)	(2.62)	(2.09)	(1.64)
M2	-0.0094*	-0.0111*	-0.0108	-0.0116
	(2.05)	(2.17)	(1.72)	(1.76)
Personal Consumption	-0.0038	-0.0043	-0.0063	-0.0043
	(1.29)	(1.32)	(1.46)	(1.14)
Personal Income	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)
Producer Price Index	-0.0198*	-0.0181*	-0.0189	-0.0201
	(2.06)	(2.10)	(1.77)	(1.73)
Retail Sales	-0.0051	-0.0069	-0.0077	-0.0091
	(1.19)	(1.43)	(1.61)	(1.17)
Durable Goods Orders	-0.0023	-0.0038	-0.0030	-0.0040
	(1.02)	(1.24)	(1.22)	(1.18)
Pre'94 FMOC	-0.0093	-0.0118	-0.0109	-0.0099
	(0.80)	(0.99)	(1.12)	(0.76)
Post'94 FOMC	-0.0092	-0.0068	-0.0086	-0.0104
	(1.21)	(1.43)	(1.32)	(0.92)
Post'94 FOMC Press Rel.	-0.0184*	-0.0196*	-0.0188	-0.0187*
	(2.12)	(2.22)	(1.69)	(2.06)

Table 1-9 (contd.)

Model:

$$\ln(\sigma_t / \sigma_{t-1}) = \beta_0 + \sum_{i=1}^{19} \beta_k AD_{kt} + u_{t,}$$

where

$$u_t = \sum_{j=1}^{2} \alpha_j u_{t-j} + \varepsilon_t,$$

and $\epsilon_t \sim N(0,1)$ i.i.d.

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.
[1]Macro regimes represent different levels of monthly growth in industrial production.

Table 1-10. Impact of Individual Macroeconomic Announcements on Implied Volatility (Regression Results for Full Sample (1983-2002) and Different Macro Regimes[1] using Call Options):

Dummy Variables for Individual Announcements	Full Sample	Low Growth	Moderate Growth	High Growth
Intercept (no announcement)	0.0056*	0.0059*	0.0054*	0.0045*
	(2.24)	(2.16)	(2.19)	(2.01)
Balance of Trade	-0.0124*	-0.0136**	-0.0118*	-0.0113
	(1.97)	(2.59)	(2.05)	(1.89)
Consumer Credit	-0.0023	-0.0028	-0.0013	-0.0021
	(0.70)	(0.81)	(0.59)	(0.48)
Construction Spending	-0.0012	-0.0018	-0.0014	-0.0012
	(1.01)	(0.95)	(0.78)	(0.69)
Consumer Price Index	-0.0118**	-0.0131*	-0.0118*	-0.0123
	(2.72)	(2.24)	(1.93)	(1.82)
Employment	-0.0184**	-0.0189**	-0.0198*	-0.0179*
	(2.99)	(2.87)	(2.01)	(2.01)
Unemployment	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)
Real GDP	-0.0042	-0.0049	-0.0055	-0.0035
	(1.29)	(1.43)	(0.99)	(1.09)
New Home Sales	0.0016	-0.0002	0.0006	0.0008
	(1.12)	(0.44)	(0.47)	(0.69)
Housing Starts	-0.0119*	-0.0133**	-0.0138*	-0.0103*
	(2.21)	(2.76)	(2.08)	(2.07)
Industrial Production	-0.0039	-0.0042	-0.0049	-0.0058
	(1.41)	(1.29)	(0.87)	(0.94)
Leading Indicators	0.0009	-0.0021	0.0027	0.0034
	(0.67)	(0.54)	(0.62)	(0.43)
M1	-0.0132*	-0.0139**	-0.0137*	-0.0151
	(2.27)	(2.61)	(1.97)	(1.73)
M2	-0.0090*	-0.0105*	-0.0109	-0.0105
	(2.05)	(2.02)	(1.76)	(1.64)
Personal Consumption	-0.0034	-0.0039	-0.0043	-0.0039
	(1.27)	(1.19)	(1.49)	(1.03)
Personal Income	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)
Producer Price Index	-0.0186*	-0.0181*	-0.0189	-0.0197
	(2.09)	(1.98)	(1.78)	(1.69)
Retail Sales	-0.0054	-0.0066	-0.0071	-0.0083
	(1.23)	(1.32)	(1.65)	(1.14)
Durable Goods Orders	-0.0014	-0.0029	-0.0025	-0.0037
	(1.02)	(1.17)	(1.22)	(1.11)
Pre'94 FMOC	-0.0092	-0.0101	-0.0108	-0.0087
	(0.73)	(0.85)	(0.82)	(0.81)
Post'94 FOMC	-0.0076	-0.0064	-0.0081	-0.0101
	(1.08)	(1.13)	(1.37)	(0.88)
Post'94 FOMC Press Rel.	-0.0174*	-0.0189*	-0.0183	-0.0185*
	(1.98)	(2.05)	(1.91)	(1.99)

Table 1-10 (contd.)

Model:

$$\ln(\sigma_t / \sigma_{t-1}) = \beta_0 + \sum_{i=1}^{19} \beta_k AD_{kt} + u_{t,}$$

where

$$u_t = \sum_{j=1}^{2} \alpha_j u_{t-j} + \varepsilon_t,$$

and $\epsilon_t \sim N(0,1)$ i.i.d.

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.
[1]Macro regimes represent different levels of monthly growth in industrial production.

Table 1-11. Impact of Individual Macroeconomic Announcements on Implied Volatility (Regression Results for Full Sample (1983-2002) and Different Macro Regimes[1] using Put Options):

Dummy Variables for Individual Announcements	Full Sample	Low Growth	Moderate Growth	High Growth
Intercept (no announcement)	0.0063* (2.29)	0.0066* (2.21)	0.0063* (2.16)	0.0046* (2.01)
Balance of Trade	-0.0137* (2.03)	-0.0149** (2.72)	-0.0138* (2.12)	-0.0153** (2.64)
Consumer Credit	-0.0032 (0.84)	-0.0043 (0.92)	-0.0021 (0.48)	-0.0026 (0.43)
Construction Spending	-0.0019 (1.16)	-0.0018 (0.87)	-0.0033 (0.57)	-0.0017 (0.56)
Consumer Price Index	-0.0126** (2.97)	-0.0142** (2.73)	-0.0134* (2.03)	-0.0141 (1.91)
Employment	-0.0194** (3.12)	-0.0195** (3.01)	-0.0183* (2.18)	-0.0193** (2.94)
Unemployment	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)
Real GDP	-0.0051 (1.43)	-0.0061 (1.27)	-0.0067 (0.98)	-0.0049 (0.86)
New Home Sales	0.0021 (1.27)	-0.0007 (0.66)	0.0012 (0.27)	0.0008 (0.66)
Housing Starts	-0.0129* (2.29)	-0.0148** (3.12)	-0.0153* (2.26)	-0.0138* (2.09)
Industrial Production	-0.0049 (1.61)	-0.0052 (1.19)	-0.0047 (0.83)	-0.0059 (0.96)
Leading Indicators	0.0016 (0.81)	-0.0038 (0.42)	0.0031 (0.49)	0.0041 (0.67)
M1	-0.0148* (2.31)	-0.0156** (2.93)	-0.0136* (2.08)	-0.0143 (1.72)
M2	-0.0098* (2.11)	-0.0113* (2.21)	-0.0096 (1.79)	-0.0112 (1.81)
Personal Consumption	-0.0039 (1.43)	-0.0056 (0.96)	-0.0048 (1.21)	-0.0051 (1.27)
Personal Income	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)
Producer Price Index	-0.0198* (2.15)	-0.0196** (2.74)	-0.0189* (1.97)	-0.0189 (1.76)
Retail Sales	-0.0063 (1.31)	-0.0063 (1.02)	-0.0058 (1.03)	-0.0086 (1.09)
Durable Goods Orders	-0.0021 (1.18)	-0.0038 (1.41)	-0.0041 (1.16)	-0.0037 (1.22)
Pre'94 FMOC	-0.0099 (0.87)	-0.0116 (0.87)	-0.0127 (0.99)	-0.0106 (0.63)
Post'94 FOMC	-0.0091 (1.23)	-0.0082 (0.91)	-0.0086 (1.31)	-0.0082 (0.99)
Post'94 FOMC Press Rel.	-0.0192* (2.14)	-0.0192** (2.73)	-0.0183 (1.87)	-0.0201** (2.61)

Table 1-11 (contd.)

Model:

$$\ln(\sigma_t / \sigma_{t-1}) = \beta_0 + \sum_{i=1}^{19} \beta_k AD_{kt} + u_{t,}$$

where

$$u_t = \sum_{j=1}^{2} \alpha_j u_{t-j} + \varepsilon_t,$$

and $\epsilon_t \sim N(0,1)$ i.i.d.

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.
[1]Macro regimes represent different levels of monthly growth in industrial production.

Table 1-12. Impact of Macroeconomic Announcements on Implied Volatility (Call-Put Avg.)

Panel A. Weighted Average of Implied Volatilities (method 1)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0541 3.011**	0.029 2.726**
2	t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)	2.859**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0532	0.029
4	Kruskal-Wallis stat. (H_0: med_{ann} = med_{noann})	31.791**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})$<0 z-stat. ($H_0$: percentage = 0.5)	60.89% 3.78**	39.11% 3.69**
6	χ^2-stat. (H_0: $percentage_{ann}$ = $percentage_{noann}$)	22.127**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the weighted average of the implied volatilities of the two nearest-the-money call and put options such that average strike price equals the underlying asset price. At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Panel B. Weighted Average of Implied Volatilities (method 2)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0621 2.931**	0.032 2.709**
2	t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)	2.964**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0643	0.039
4	Kruskal-Wallis stat. (H_0: med_{ann} = med_{noann})	31.068**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})$<0 z-stat. ($H_0$: percentage = 0.5)	59.82% 3.27**	40.18% 3.03**
6	χ^2-stat. (H_0: $percentage_{ann}$ = $percentage_{noann}$)	22.003**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the equally weighted average of the implied volatilities of all traded options. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-12 (contd.)
Panel C. Implied Volatilities Derived from Modified Option Pricing Formula

		Trading Days with Announcements	Trading Days without Announcements
1	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0566 3.012**	0.019 2.802**
2	**t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)**	2.973**	
3	**Median of $\ln(\sigma_t/\sigma_{t-1})$**	-0.0566	0.034
4	**Kruskal-Wallis stat.** **(H_0: med_{ann} = med_{noann})**	32.041**	
5	**Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})$<0** **z-stat. ($H_0$: percentage = 0.5)**	61.68% 3.98**	38.32% 3.73**
6	**χ^2-stat.** **(H_0: $percentage_{ann}$ = $percentage_{noann}$)**	22.214**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the average implied volatility of the two nearest-the-money call and put options derived from the modified option pricing formula where the underlying asset price is assumed to follow a Weibull distribution. At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-13. Impact of Macroeconomic Announcements on Implied Volatility (Call Options)
Panel A. Weighted Average of Implied Volatilities (method 1)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0536 2.989**	0.031 2.702**
2	t-stat. (H_0: $mean_{ann} = mean_{noann}$)	2.922**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0593	0.028
4	Kruskal-Wallis stat. (H_0: $med_{ann} = med_{noann}$)	31.668**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$ z-stat. (H_0: percentage = 0.5)	61.42% 3.83**	38.58% 3.61**
6	χ^2-stat. (H_0: $percentage_{ann} = percentage_{noann}$)	23.009**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the weighted average of the implied volatilities of the two nearest-the-money call options such that average strike price equals the underlying asset price. At the beginning of every week, two nearest-the-money call options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Panel B. Weighted Average of Implied Volatilities (method 2)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0639 2.945**	0.027 2.816**
2	t-stat. (H_0: $mean_{ann} = mean_{noann}$)	3.007**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0628	0.023
4	Kruskal-Wallis stat. (H_0: $med_{ann} = med_{noann}$)	30.154**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$ z-stat. (H_0: percentage = 0.5)	59.05% 3.16**	40.95% 3.21**
6	χ^2-stat. (H_0: $percentage_{ann} = percentage_{noann}$)	24.192**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the equally weighted average of the implied volatilities of all traded call options. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-13 (contd.)

Panel C. Implied Volatilities Derived from Modified Option Pricing Formula

		Trading Days with Announcements	Trading Days without Announcements
1	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0574 2.975**	0.022 2.764**
2	**t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)**	2.823**	
3	**Median of $\ln(\sigma_t/\sigma_{t-1})$**	-0.0589	0.030
4	**Kruskal-Wallis stat.** **(H_0: med_{ann} = med_{noann})**	31.922**	
5	**Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})$<0** **z-stat. ($H_0$: percentage = 0.5)**	61.83% 3.82**	38.17% 3.86**
6	**χ^2-stat.** **(H_0: $percentage_{ann}$ = $percentage_{noann}$)**	24.159**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the average implied volatility of the two nearest-the-money call options derived from the modified option pricing formula where the underlying asset price is assumed to follow a Weibull distribution (Savickas [2002]). At the beginning of every week, two nearest-the-money call options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-14. Impact of Macroeconomic Announcements on Implied Volatility (Put Options)
Panel A. Weighted Average of Implied Volatilities (method 1)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0578 3.108**	0.034 2.813**
2	t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)	3.109**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0586	0.024
4	Kruskal-Wallis stat. (H_0: med_{ann} = med_{noann})	30.664**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$ z-stat. (H_0: percentage = 0.5)	61.11% 3.69**	38.89% 3.27**
6	χ^2-stat. (H_0: $percentage_{ann}$ = $percentage_{noann}$)	22.863**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the weighted average of the implied volatilities of the two nearest-the-money put options such that average strike price equals the underlying asset price. At the beginning of every week, two nearest-the-money put options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Panel B. Weighted Average of Implied Volatilities (method 2)

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0663 2.861**	0.031 2.792**
2	t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)	3.104**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0672	0.038
4	Kruskal-Wallis stat. (H_0: med_{ann} = med_{noann})	30.855**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$ z-stat. (H_0: percentage = 0.5)	60.78% 3.38**	39.22% 3.19**
6	χ^2-stat. (H_0: $percentage_{ann}$ = $percentage_{noann}$)	21.962**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the equally weighted average of the implied volatilities of all traded put options. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-14 (contd.)
Panel C. Implied Volatilities Derived from Modified Option Pricing Formula

		Trading Days with Announcements	Trading Days without Announcements
1	Mean of $\ln(\sigma_t/\sigma_{t-1})$ t-stat. (H_0: mean = 0)	-0.0586 3.037**	0.026 2.941**
2	t-stat. (H_0: $mean_{ann}$ = $mean_{noann}$)	3.004**	
3	Median of $\ln(\sigma_t/\sigma_{t-1})$	-0.0606	0.036
4	Kruskal-Wallis stat. (H_0: med_{ann} = med_{noann})	31.973**	
5	Percentage of trading days $\ln(\sigma_t/\sigma_{t-1})<0$ z-stat. (H_0: percentage = 0.5)	62.05% 3.73**	37.95% 3.66**
6	χ^2-stat. (H_0: $percentage_{ann}$ = $percentage_{noann}$)	23.168**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the average implied volatility of the two nearest-the-money put options derived from the modified option pricing formula where the underlying asset price is assumed to follow a Weibull distribution (Savickas [2002]). At the beginning of every week, two nearest-the-money put options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests.

Table 1-15. Impact of Individual Macroeconomic Announcements on Implied Volatility (Initial Regression Results for Full Sample (1983-2002) and Different Methods for Calculation of Implied Volatilities (Call-Put Avg.):

Intercept (no announcement)	0.0057* (2.24)	0.0056* (2.18)	0.0057* (2.21)	0.0051* (2.22)
Balance of Trade	-0.0137* (1.99)	-0.0139* (2.03)	-0.0127* (2.07)	-0.0131* (2.04)
Consumer Credit	-0.0025 (0.72)	-0.0026 (0.79)	-0.0016 (0.63)	-0.0023 (0.69)
Construction Spending	-0.0015 (0.99)	-0.0019 (0.99)	-0.0012 (0.86)	-0.0011 (0.82)
Consumer Price Index	-0.0119** (2.96)	-0.0120** (2.93)	-0.0121** (2.89)	-0.0116** (2.98)
Employment	-0.0193** (3.11)	-0.0196** (2.99)	-0.0196** (2.63)	-0.0199** (3.16)
Unemployment	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)	(same dummy as employment)
Real GDP	-0.0039 (1.31)	-0.0038 (1.31)	-0.0058 (1.03)	-0.0043 (1.38)
New Home Sales	0.0018 (1.16)	-0.0016 (1.09)	0.0009 (0.51)	0.0021 (0.98)
Housing Starts	-0.0131* (2.19)	-0.0135* (2.08)	-0.0141* (2.06)	-0.0146* (2.23)
Industrial Production	-0.0042 (1.52)	-0.0044 (1.49)	-0.0052 (0.96)	-0.0049 (1.63)
Leading Indicators	0.0011 (0.69)	-0.0016 (0.64)	0.0029 (0.51)	0.0027 (0.58)
M1	-0.0141* (2.30)	-0.0144* (2.28)	-0.0144* (2.01)	-0.0153* (2.31)
M2	-0.0094* (2.05)	-0.0095* (2.11)	-0.0089* (2.03)	-0.0088* (2.12)
Personal Consumption	-0.0038 (1.29)	-0.0041 (1.26)	-0.0057 (1.14)	-0.0049 (1.36)
Personal Income	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)	(same dummy as pers. cons.)
Producer Price Index	-0.0198* (2.06)	-0.0193* (2.02)	-0.0197* (1.99)	-0.0201* (2.10)
Retail Sales	-0.0051 (1.19)	-0.0056 (1.23)	-0.0074 (0.87)	-0.0068 (1.23)
Durable Goods Orders	-0.0023 (1.02)	-0.0024 (1.13)	-0.0022 (0.92)	-0.0036 (1.19)
Pre'94 FMOC	-0.0093 (0.80)	-0.0098 (0.89)	-0.0123 (0.74)	-0.0118 (0.92)
Post'94 FOMC	-0.0092 (1.21)	-0.0087 (1.24)	-0.0092 (1.06)	-0.0104 (0.94)
Post'94 FOMC Press Rel.	-0.0184* (2.12)	-0.0192* (2.14)	-0.0190* (2.09)	-0.0196* (2.19)

Table 1-15 (contd.)

Model:

$$\ln(\sigma_t / \sigma_{t-1}) = \beta_0 + \sum_{i=1}^{19} \beta_k AD_{kt} + u_{t,}$$

where

$$u_t = \sum_{j=1}^{2} \alpha_j u_{t-j} + \varepsilon_t,$$

and $\epsilon_t \sim N(0,1)$ i.i.d.

* and ** denote significance at 5 and 1 % level, respectively.
Values in parentheses are t-statistics.

Table 1-16. Impact of Selected Macroeconomic Announcements on Implied Volatility

		Trading Days With At Least 1 Sig. Anno.	**Trading Days without Announcements**
Call-Put Avg.	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0927 3.012**	0.027 2.716**
	t-stat. (H_0: $mean_1$ = $mean_2$)	2.921**	
Call	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0908 2.875**	0.024 2.268*
	t-stat. (H_0: $mean_1$ = $mean_2$)	2.905**	
Put	**Mean of $\ln(\sigma_t/\sigma_{t-1})$** **t-stat. ($H_0$: mean = 0)**	-0.0946 2.946**	0.030 2.291*
	t-stat. (H_0: $mean_1$ = $mean_2$)	3.002**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where $\boldsymbol{\sigma}$ is the implied volatility of the corresponding two nearest-the-money call or put options (First row reports the values for the average of the two). At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests. Significant macroeconomic variables are identified using the results in tables 9-11 for the corresponding options or their average.

Table 1-17. Impact of Selected Macroeconomic Announcements on Implied Volatility

		Trading Days With At Least 1 Sig. Anno.	Trading Days without Sig. Announcements
Call-Put Avg.	Mean of $\ln(\sigma_t/\sigma_{t-1})$	-0.0927	0.018
	t-stat. (H_0: mean = 0)	3.012**	1.673
	t-stat. (H_0: $mean_1 = mean_2$)	2.589**	
Call	Mean of $\ln(\sigma_t/\sigma_{t-1})$	-0.0908	0.019
	t-stat. (H_0: mean = 0)	2.875**	2.011*
	t-stat. (H_0: $mean_1 = mean_2$)	2.836**	
Put	Mean of $\ln(\sigma_t/\sigma_{t-1})$	-0.0946	0.023
	t-stat. (H_0: mean = 0)	2.946**	2.116*
	t-stat. (H_0: $mean_1 = mean_2$)	2.941**	

Statistics are calculated for $\ln(\sigma_t/\sigma_{t-1})$, where σ is the implied volatility of the corresponding two nearest-the-money call or put options (First row reports the values for the average of the two). At the beginning of every week, two nearest-the-money options are reselected and the implied volatility changes are calculated accordingly for the following week. * (**) indicates significance at 5% (1%) level for the two-tailed tests. Significant macroeconomic variables are identified using the results in tables 9-11 for the corresponding options or their average.

CHAPTER 2
ON-THE-RUN VS. OFF-THE-RUN TREASURY SECURITY YIELD SPREAD: SOME STYLIZED FACTS

Introduction

It is a well-known fact that on-the-run Treasury securities (i.e., most recently issued Treasury securities) trade at higher prices relative to off-the-run Treasury securities (i.e., securities issued at previous auctions with nearly identical terms to maturity) (Boudoukh and Whitelaw [1993], and Sundaresan [1994]). It is also well known that the spread in the yield of these securities converges to zero towards the next issuance date (Krishnamurthy [2002]), i.e., when the current on-the-run issue becomes just-off-the-run issue (off-the-run issue hereafter) and there is a new on-the-run issue traded in the market.

Economic theory suggests that prices are set in the market by marginal investors, who are usually assumed to be rational and whose actions leave no room for arbitrage opportunities. However, the existence of the above-mentioned spread suggests that there might be an arbitrage opportunity in the Treasury securities market. To take advantage of such an arbitrage, one might adopt the following trading strategy: Sell the on-the-run Treasury security short, right after the issuance when the spread is high. Simultaneously buy the off-the-run security and hold it until the next issue date. At the end of the auction cycle, unwind the position when the spread is close to zero. Krishnamurthy [2002] finds

that despite the systematic convergence of the on-the-run vs. off-the-run Treasury security yield spread, the average profits from such trade is close to zero when repo rates are taken into consideration.

This arbitrage trading strategy, however, was employed by Long Term Capital Management (LTCM). In a PBS broadcast documentary about Long Term Capital Management, one of LTCM's managers mentioned that they were "collecting the dimes" in the market, suggesting that the above-mentioned trading strategy returns very small profits and has to be repeated frequently to be successful.

Does the existence of the on-the-run vs. off-the-run Treasury spread really present evidence for Treasury market inefficiency? Previous studies focused on three possible explanations for this discriminatory pricing of nearly identical securities: possible squeezes due to the when-issued trading, low rates available to the holders of on-the-run Treasury securities in the repo market, and the demand for liquidity by the investors in Treasury securities market. However, previous studies failed to present their arguments either for a comprehensive list of securities available in the Treasury securities market or for a long time period which would allow testing the effects of some major changes in the market. Hence, this study takes a different approach in attempting to investigate the previous arguments and to construct some stylized facts about the spread between the yields of on-the-run and off-the-run Treasury securities by focusing on the possible effects of the above-mentioned factors on the bid-ask spreads of the Treasury securities. The new approach allows this study to assemble the stylized facts both for the majority of the Treasury securities and for a time period going back to the mid 1970's. In the

following parts of this study I will review each of these issues both in the discussion of the US Treasury Market, and in the literature review section.

In order to better understand the market dynamics, one must consider the unique features associated with the Treasury securities markets. Therefore, I will first provide some background information about the Treasury securities markets in the US. Then, I will review the related literature on the subject. Finally, I will construct some stylized facts about the spread between the yields of on-the-run and off-the-run Treasury securities. The study concludes with a summary of results and implication for further research.

US Treasury Securities Market

US Treasury securities are initially offered to investors via an auction mechanism that is surrounded by several interconnected markets. These markets consist of a primary market, when-issued market, secondary market, and repo market. The interaction between these markets is often complex, which makes it difficult to construct underlying theoretical models that can clearly test the hypothesized relationships among the various factors.

The US Treasury issues short, medium and long-term government debt. The Federal Reserve System through its automated book-entry system handles both the initial offerings and the subsequent transfers of these securities. Note that the Federal Reserve also conducts the monetary policy, including the open market operations, where the Federal Reserve tries to influence the money supply, credit conditions and the interest rates through purchases and sales of Treasury securities. Hence, it can be said that the

Federal Reserve operates as an agent of the US Treasury in this market where it directly participates both in the issuance and monitoring process of government debt.

Since US Treasury securities are the most liquid and least risky investment instruments available, they have been held and traded by investors throughout the world. These include central banks, pension funds, insurance companies, US and foreign commercial banks, corporations, local governments, and households. The US Treasury market consists of four interconnected markets: Primary market, when-issued market, secondary market, and repo market.

Primary Market

US Treasury securities are sold to competitive and noncompetitive bidders via an auction mechanism that has undergone several changes in the last decades. Before 1970, the US Treasury issued them through subscription offerings, exchange offerings, and advanced refunding. Subscription offerings were new issues sold with a preset interest rate and fixed price. Exchange offerings allowed investors to exchange maturing issues with new securities at a fixed price, whereas advanced refunding allowed outstanding securities to be exchanged prior to their maturities. In 1970, the Treasury started to allow investors to bid their prices for a preset coupon rate. After 1974, the Treasury stopped setting the coupon rate prior to the auction and investors were allowed to bid on the basis of yields. That same method has been maintained as the current mechanism of choice by the Treasury to auction its securities with the following exception:

Until September 1993, all auctions were sealed-bid discriminatory (multiple-price) auctions. After that date, the Treasury started experimenting with the uniform-price Dutch auction procedure in the auction of monthly two-year and five-year Treasury

notes. Finally, at the end of 1997 the Treasury announced that it will only conduct uniform-price Dutch auctions, and gradually switched to that procedure for all different maturity securities.

Since the end of 1974, the Treasury has been accepting competitive and noncompetitive bids for its auctions. For a competitive bid, primary dealers and large institutional investors submit both prices and quantities. Each competitive bidder is allowed to submit multiple bids. Successful competitive bidders may or may not get the entire quantity they bid for, because the total quantity bid by the noncompetitive bidders is subtracted from the aggregate amount of the security that the Treasury wants to offer in the auction, to determine the amount that will be sold to competitive bidders. On the other hand, noncompetitive bidders are assured of the quantity they bid for.

In a discriminatory auction, the Treasury acts as a monopolist and each successful competitive bidder pays the price it bid. Noncompetitive bidders however pay the quantity-weighted average price that is established in the competitive tender.

In a Dutch (single-price) auction, however, both the successful competitive and noncompetitive bidders pay the lowest successful price (market clearing price) that is established in the competitive tender.

To increase competition and get better results from the auctions, the Treasury limited the noncompetitive bids from the public to 5 million dollars in size. In addition, a single bidder's net long position in the auction at any yield including futures, forwards and when-issued market may not exceed 35% of the total auctioned amount (we will discuss this issue in further detail with when-issued trading and squeezes later in the study).

Currently, the primary market for Treasury securities usually follows a regular auction cycle for Treasury securities with different maturities:

13-week and 26-week bills are usually offered each week. For a typical week, the next auction date and the offering amount is announced on Thursday, and the bills are auctioned the following Monday. They are issued on the Thursday following the auction. Holidays may affect the announcement, auction, and issuance date.

52-week bills: This security had its last auction on February 27^{th}, 2001. During the time covered by my data a 52-week bill was issued every four weeks.

2-year notes are issued once a month. The auctions are generally announced near the middle of each month and auctioned one week later. They are usually issued on the last day of each month. If the last day of the month is a Saturday, Sunday, or Federal holiday, the notes are issued on the first business day of the following month.

Until June 30th, 1998 the 5-year notes were issued on a monthly basis following the same schedule as the 2-year note auctions. Currently, the 5-year note auctions are usually announced on the first Wednesday of February, May, August, and November. They are generally auctioned during the second week of February, May, August, and November, and are issued on the 15th of the same month. If the 15th of the month falls on a Saturday, Sunday, or Federal holiday, the securities are issued on the next business day.

10-year note auctions follow the same schedule as the current 5-year note auction schedule.

30-year bond auctions are usually announced along with 5-year and 10-year notes on the first Wednesday of February and August. They are generally auctioned during the

second week of February and August and issued on the 15th of the same month. If the 15th of the month falls on a Saturday, Sunday, or Federal holiday, the securities are issued on the next business day. However, prior to the fall of 1993, 30-year bond auctions were held quarterly, and they were following the same schedule as the current 5-year and 10-year note auctions.

For Treasury notes and bonds, each auction follows a typical sequence: First, the Treasury announces the auction date and the amount to be sold, usually one week prior to the auction date. Second, when-issued trading starts (on a yield basis since the coupon is not known until after the auction results are announced). Third, on the auction date, bids are made to the New York Fed by 1:00 PM. Usually within one hour the Treasury announces the coupon and the distribution of the issue. On the next day, the issue trades on a price basis in the when-issued market, and trading continues until the securities are issued. The issuance usually takes place five days after the auction date.

When-issued Market

Potential bidders for an auction can hold long or short positions in a forward trading market in Treasury securities even before they are issued. This forward trading is known as the "when, as, and if issued" (or simply when-issued) market, and it is an integral part of the Treasury bidding and distribution system.

Although not every investor who participates in when-issued market makes a bid in the real auction, the existence of this forward trading market makes it possible for some bidders to enter the auction with prior long or short positions. Trading in the when-issued market typically occurs between the auction announcement date and the issue date (usually a five trading days period for notes and bonds). Investors who enter the auction

with an existing short position from the when-issued market will typically need to buy the securities to unwind their positions. When dealers sell short in the when-issued market, they sell securities that they don't own, assuming they can acquire them later. They can cover their short position either by participating in the auction (primary market) or by borrowing the securities (repo market). Hence, if many investors carry over short positions from the when-issued market, it will create a so-called "short squeeze." This effect will have important implications on the price behavior of the security in the secondary market as well as the repo rates behavior in the repo market. Consequently, these carried-over positions from the when-issued market might affect investors' bidding strategies and the demand for the Treasury securities during and after the auction.

For example, Salomon Brothers and its customers were able to control 94% of the auctioned 2-year note in May 1991. Subsequently, the price difference between the on-the-run and off-the-run 2-year notes reached an unusually high gap and the "special" rate in the repo market (to be explained in the next section) dropped significantly, which then led to an investigation and the famous "Joint Report on the Government Securities Market [1992]" published by the Department of the Treasury, the Securities and Exchange Commission, and the Board of Governors of the Federal Reserve System. The investigation found that primary dealers had an average net short position carried-over from when-issued trading equal to almost 40% of the notes and bonds awarded to them in Treasury auctions between January 1990 and September 1991. The above-mentioned report defines a squeeze as:

"...to refer to a shortage of supply relative to demand for a particular security, as evidenced by a movement in its price to a level that is out of line with prices of comparable securities- either in outright trading or in financing arrangements."

This reaction and several other similar investigations and reports by the regulators, and the above-mentioned 35% rule show that a squeeze, either due to the carried-over positions from the when-issued market or due to a high concentration of ownership by a single bidder at the auction, could affect prices in the secondary market as well as the rates in the repo market.

In addition, dealers and institutional investors use the information from the when-issued market to assess the depth of the forthcoming issue because the activity in the when-issued market can be a good indicator of future demand for the following on-the-run issue. Hence, forward trading of Treasury securities in the when-issued market permits the sharing of information. With that goal in mind, the US Treasury had officially sanctioned when-issued trading in August 1981 to encourage trading of the securities immediately after the auction announcement. Later in this study, I will revisit this issue and examine whether this decision had an impact on the market behavior.

Secondary Market

There is also a very active secondary market for Treasury securities where investors buy and sell the auctioned securities after issuance. Treasury bills have the largest volume outstanding and the most active secondary market trading of any money market instrument, followed by the 30-year Treasury bonds (Cook and LaRoche [1998], and Krishnamurthy [2002]). This secondary market is a dealer's market with twenty-five primary dealers and more than 1,500 other smaller dealers. The primary dealers bid

regularly at Treasury auctions both for their own accounts and for their customers. In addition, they act as market makers in the sense that they maintain liquidity in Treasury securities. Using either the primary dealers or the other smaller dealers, investors can trade Treasury securities in the secondary market.

Repo Market

In addition to the secondary markets for Treasury securities, investors can borrow and lend Treasury securities overnight on specified terms in the "repo market." Since government securities make excellent collateral, dealers use the repo market extensively to leverage their positions. The repo market allows dealers to transfer large amounts of funds, for a very short time, and with very little sensitivity to the changes in the underlying security's value. A repo contract consists of the sale of a security with a simultaneous forward contract to buy it back at a specified price, usually next day. A reverse repo contract however, consists of the purchasing of the security and the delivery of cash. To unwind a reverse repo position (usually next day), the security is delivered and the cash is taken back.

One important issue, however, is that exactly the traded securities must be delivered. Moreover, if multiple securities are sold short in the same transaction all must be delivered leaving no room for partial delivery. The inability to deliver any of them would be very costly because the penalties for failure to deliver are proportional to the entire trade, not just the part failed to be delivered. Therefore, two nearly identical securities (i.e., on-the-run and off-the-run Treasury securities) can and usually do have different collateral values in the repo market (One important recent exception to this rule was the Treasury's reaction to the September 11 terrorist attacks and the events that

followed them in the market (Fleming and Garbade [2002]). Following the attacks, many sellers failed to deliver the Treasury securities on time, and settlement failures increased from $1.7 billion a day during the preceding week to $190 billion a day during the following week of the attacks. Consequently, the Treasury reopened some of the on-the-run issues to allow the short participants to close their positions.).

Scarcity of one security (on-the-run Treasury issue) might be intensified by its uniqueness to cover short positions in repo/reverse repo transactions or by the short positions carried over from the when-issued market. When such scarcity increases demand for the on-the-run Treasury issues, owners of those securities can lend them by accepting cash as collateral as long as the interest they pay on that cash is low enough, so that they can earn profits using the spread between that interest rate and other short-term investment rates (typically Fed funds rate). This lending process is unique for the on-the-run issues and makes it possible for their owners to earn a profit by utilizing the above-mentioned difference between the "special" rate and the general collateral rate in the repo market. The low repo rate the owners of the on-the-run issue pay is called the "special repo rate" and hence this phenomenon is known as the "specialness" of the on-the-run Treasury securities (Sundaresan [1994], and Duffie [1996]).

Related Literature

The auctioning and trading of Treasury securities have drawn the attention of both theoretical and empirical studies for a long time.

Theoretical Studies

Early auction theories (e.g., Vickrey [1961]) tend to focus on auction design with expected revenues in mind. One weakness of such early auction theory models is that they present a single-unit auction environment that is inappropriate to apply to the US

Treasury markets. Few auction models among them (e.g. Maskin and Riley [1989]) allow both competitive and non-competitive bidders to try to purchase the security. Moreover, most of this earlier work ignores the existence of the preceding forward trading (when-issued market). Bikchandani [1988] and Bikchandani and Huang [1989] are the first models to incorporate the repeated nature of the auctions and the existence of a secondary market. But they still treat Treasury auctions as common value auctions, although the existence of the forward trading in Treasury securities makes the effect of the long and short positions carried over from forward trading an inevitable factor affecting both the prices in secondary market and the rates in repo market. Note that when-issued trading continues only until the issuance of the security whose auction was announced. Hence, the above-mentioned effect does not exist for the off-the-run security, which might be one of the factors causing the yield spread between on-the-run and off-the-run securities.

In addition, none of the existing term-structure models explicitly address the fact that on-the-run Treasury securities are more liquid than off-the-run securities, and hence, they trade at a higher price.

More recent studies, like Duffie [1996], develop theoretical models of bond and repo markets, where shorting is allowed and both specialness and liquidity premiums co-exist. In addition, Boudoukh and Whitelaw [1993] and Holmstrom and Tirole [1999] present models where investors have a demand for a relatively more liquid asset, but there is a shortage of this asset, hence its price rises above other assets. Krishnamurthy [2002] utilizes an extension of Duffie [1996]'s model to identify the economic factors behind the on-the-run/off-the-run Treasury spread and the "specialness."

However, the need for a theoretical model, which incorporates the forward trading into the equilibrium by allowing bidders to condition their bids according to their short or long positions from the when-issued market, still exists. Idiosyncratic costs of covering their positions might separate bidders from each other, leading them to value the Treasury securities privately, especially when even nearly identical securities cannot be used as substitutes as explained in the previous section. Such differences in the valuation of nearly identical securities might allow different prices for those securities to co-exist even in an efficient market.

While an extensive literature has investigated Treasury auctions and term-structure rates, relatively little research has investigated the yield spread between on-the-run and off-the-run securities in the context of pricing, efficiency, and the interconnectedness of the primary, when-issued, secondary, and repo markets.

Empirical Studies

Many empirical studies present evidence for the differences between on-the-run and off-the-run Treasury securities. Evidence presented by these studies can be classified into three major arguments attempting to explain the discriminatory pricing of on-the-run vs. off-the-run Treasury securities:

1- Squeezes: Cornell and Shapiro [1989] is among the early studies to investigate the "mispricing" in the Treasury securities market. Cornell [1993] specifically targets the squeezes in the Treasury securities market between 1986 and 1991, and it tests the hypothesis that the bid-ask spreads during a squeeze would widen due to the expectation that the dealers will assume that they are trading with parties with superior information (i.e., dealers or brokers who cause or control the squeeze). However, its results present

evidence that the bid-ask spreads are actually relatively very narrow during the squeezes. Moreover, it finds that the bid-ask spread difference between on-the-run and off-the run securities widens towards later in the auction cycle, where the bid-ask spread of the off-the-run security increases shortly after the issuance of the on-the-run security, whereas the bid-ask spread of the on-the-run security stays relatively narrow. Cornell [1993] relates this to the "popularity" and "higher liquidity" of the on-the-run security. Hence, its results support that the trading volume has a greater impact on bid-ask spreads than the expected adverse selection. This finding is particularly important for this study because it uses the bid-ask spread difference as one of the possible explanatory variables for the yield spread between on-the-run and off-the-run Treasury securities.

2- Specialness: Sundaresan [1994] shows different behaviors of the two securities in both secondary and repo markets around the auction dates, and investigates the issue from the auction methodology point of view. It concludes that the mechanism of an auction affects the on-the-run securities differently than the off-the-run securities. In addition, Sundaresan [1994] presents evidence that the high bid-ask spread differences between on-the-run and off-the-run Treasury securities are also associated with high price differences between those securities. As mentioned above, I will investigate this relationship for a broad date range and for a variety of Treasury securities with different maturities in this study. Jordan and Jordan [1997] and Buraschi and Menini [1999] present empirical evidence for specialness of the on-the-run securities in repo market, and link this specialness to the discriminatory pricing and the liquidity premium in the secondary market. Their findings confirm Duffie [1996]'s earlier theoretical work which employs a simple multiperiod model with the assumptions of Cox, Ingersoll, and Ross

[1985] to derive the relationship between the relative price differential, and the degree of specialness (as measured by the ratio of special repo rate to the general collateral rate in the repo market). Krishnamurthy [2002] takes one step further and incorporates the repo rates as the cost of carrying the arbitrage trading of the on-the-run and off-the-run Treasury securities. Krishnamurthy [2002] also attempts to identify the macroeconomic factors that might cause the unexpected behavior in the Treasury markets, and presents evidence that the supply of the on-the-run issue (amount of the most recent auction) and demand for liquidity in the market (measured by CPBill-TBill spread, after deducting the default risk premium (measured by AAA-BAA spread)) have significant effects on the spread between on-the-run and off-the-run Treasury securities. However, it has limited data about the special repo rates for a very short time period and only for 30-year Treasury bonds. In this study, I will examine the effects of the relative supply of the on-the-run issue and the demand for liquidity on a most of the Treasury securities for a time period between 1975 and 1999.

3- Demand for Liquidity: In addition to theoretical studies focusing on liquidity and its effects on valuation of securities (e.g., Amihud and Mendelson [1986], Holmstrom and Tirole [1999]), empirical studies like Stock and Watson [1989] and Kashyap, Stein and Wilcox [1993] try to identify macroeconomic factors affecting the liquidity demand in the market. Moreover, Amihud and Mendelson [1991], Boudoukh and Whitelaw [1993], and Longstaff [2003] present evidence that demand for liquidity plays an important role in valuation of securities in the Treasury securities market. Amihud and Mendelson [1991] and Boudoukh and Whitelaw [1993] show that discriminatory pricing is possible due to differences in liquidity, even in an efficient

market, using data from US and Japanese government securities markets, respectively. In addition, Longstaff [2003] finds that the yield spread between nearly identical securities is serially correlated and the credit spread, changes in money market mutual funds holdings and Treasury buybacks (supply) play an important role in explaining the yield spreads between US Treasury securities and Refcorp bonds.

Data

I obtain daily data on Treasury securities from the CRSP Daily Treasuries File. The CRSP US Treasury Database is assembled by the Center for Research in Security Prices at the Graduate School of Business, University of Chicago. CRSP provides complete historical descriptive information and market data including daily closing quotes, returns, accrued interest, yields, and durations beginning in 1961. However, auction data obtained from the US Treasury's webpage is available back to 1975, where I obtained the auction dates, security types, maturity information, auctioned amount, auction results, etc. Hence, this study constructs stylized facts about the on-the-run vs. off-the-run Treasury securities yield spread for 1975-1999.

In addition, I also obtain data on daily commercial paper rates and AAA-BAA commercial bond spread from the US Treasury's webpage for 1986-1999 (used as a proxy for demand for liquidity (Krishnamurthy [2002])).

On-the-run vs. Off-the-run Yield Spread

This section of the study provides some significant stylized facts about the yield spread between on-the-run and off-the-run Treasury securities. During my sample period the Treasury auctioned 13-week, 26-week, 52-week, 2-year, 3-year, 5-year, 7-year, 10-

year, 15-year, 20-year and 30-year securities with different auction cycles. For each different auction cycle (i.e., weekly, monthly, quarterly, and semi-annually), at least one Treasury security is included in the sample to provide a representative group of securities and to include those with relatively stable and continuous auction history. In addition, the results are very consistent throughout securities with different maturities. Hence, 13-week, 26-week, 2-year, 5-year, 10-year, and 30-year Treasury securities are chosen to illustrate stylized facts about the yield spread between on-the-run and off-the-run Treasury securities. In Tables 2-1 through 2-6, the numbers shown are the average daily yield spread levels for the corresponding sub-period of the auction cycle for the appropriate Treasury security, which are calculated using the midpoint of bid and ask from CRSP Daily Treasuries File, i.e.

$\text{Spread}_t = Y_{N,t} - Y_{K,t}$, where

$Y_{N,t}$ = Yield to maturity on the most recently issued (on-the-run) security that matures at time (t+m),

$Y_{K,t}$ = Yield to maturity on the previously issued (off-the-run) security that matures at time (t+m-1).

For example, Table 2-1 presents the average daily spread levels for 13-week T-Bills on each day of the auction cycle (weekly) for the whole sample period (first row, 1975-1999), as well as for each year. An auction cycle is defined as the period from the first trading day of the on-the-run issue on the secondary market to the last trading day of that issue as on-the-run (i.e., next day there is a new on-the-run issue in the market). The numbers in the first row of each cell are the average daily spread levels shown in basis points. The second rows present the t-statistics for the null hypothesis that the average

spread is zero. Finally, the third rows present Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series. All of the average spread levels during the auction cycle (i.e., when the most recently issued security is still "on-the-run") are significantly different from zero at 1% level, except for the last column of the auction cycle, where all spreads are significant at 5% level. Significance levels of the average spreads for the corresponding sub-periods of the auction cycle follow almost an identical pattern for the securities in the sample with different maturities (Tables 2-1 through 2-6). Year-by-year statistics are only reported in Tables 2-1 and 2-2 because notes and bonds have 12 or fewer auctions per year.

For longer-term maturity securities, the average daily yield spread level is calculated by taking the average of the daily spread levels over the corresponding auction cycle's sub-periods. For example, 2-year Treasury notes have a monthly auction cycle. Therefore, the auction cycle is divided into weeks, and the daily spread level averages are calculated within each of these weeks. Since a month does not have exactly four weeks, remaining trading days before the next issuance are added to the fourth week in the regular auction cycle. Since the auction cycle changes for 5-year and 30-year securities (i.e., change from monthly to quarterly auctions for 5-year notes in June 30th, 1998 , and change from quarterly to semi-annually auctions for 30-year bonds in the fall of 1993), their new auction cycles are divided into the same number of sub-periods as before the changes to allow consistency in the comparisons.

Confirming the results of Krishnamurthy [2002], I also find that the spread starts at a maximum at the beginning of the auction cycle and converges to zero towards the

next issuance date for all of the Treasury securities in the sample. Moreover, moving horizontally from left to right on Tables 2-1 through 2-6, I find that this trend in the spread behavior persists on a year-by-year basis. Figures 2-1 through 2-3 might help the reader to visualize this trend better for Treasury securities with different maturities.

Another interesting trend visible is that the spread across different maturity securities starts low at the beginning (1975), then reaches a peak in 1983, and then slowly decreases until 1990. Finally, the spread takes another peak in 1997. After that point there is a dramatic decrease in the spread levels across all securities. The years 1998 and 1999 seem to have the smallest spread levels for all of the securities in our sample. This fact might be noteworthy for further studies attempting to identify factors affecting the spread. One possible reason for this dramatic drop might be the change in the auctioning method used by the US Treasury. As mentioned earlier, towards the end of 1997 the Treasury announced that it was planning to gradually shift from multi-price discriminatory auctions to unit-price (Dutch) auctions. Starting the beginning of 1998, the Treasury started selling all Bills using a Dutch auction procedure. For the notes and bonds, the transition was more gradual, alternating methods at the beginning of 1998 and later switching totally to Dutch auctions. This issue will be revisited in the last part of the analysis.

In addition to changes in auctioning procedures, post 1997 was marked by several important events including a significant drop in the US stock market, Russia's financial crisis and its spillover to world capital markets, and the "Hedge Funds Crisis" which was associated most prominently with the collapse of the Long Term Capital Management (LTCM). Considering the fact that hedge funds like LTCM were carrying out their

investment strategies (mainly convergence trade) with relatively little capital compared to the size of the positions they were holding, it is no surprise that the above-mentioned crises -combined with a narrowed spread potentially due to the Treasury's auction procedure change- caused a major breakdown of institutions that used to benefit from such a convergence trading strategy. In Tables 2-1 through 2-6 and Figures 2-1 through 2-3, it is clear that the spreads for all securities and sub-periods are much smaller in 1998 and 1999 than the spreads during the previous periods. Finally, Tables 2-1 through 2-6 report Kruskal-Wallis statistics rejecting the hypothesis that all yield spread averages for the sub-periods of the auction cycles are equal fro the sample period 1975-1999. The significance level is 1% for all of Kruskal-Wallis statistics (critical values are given in parentheses below the K-W statistics).

There is also a distinct difference in the general spread levels with respect to the maturity length of the Treasury securities. Looking at Tables 2-1 through 2-6 together, one finds that the shortest and the longest-term maturity securities (i.e., Treasury bills and 30-year bonds) have higher spread levels than the intermediate maturity securities throughout the whole sample period. Considering the fact that the T-bills and 30-year bonds are more liquid than the Treasury notes (Cook and LaRoche [1998], Krishnamurthy [2002]), this finding confirms earlier studies which claim that higher liquidity of the on-the-run securities contribute to the discriminatory pricing in the market (Krishnamurthy [2002] and Longstaff [2003]). A higher trading activity in one security might imply higher relative demand for the on-the-run security, and hence a more significant specialness, which in the end will result in higher on-the-run vs. off-the-run yield spread (Cornell [1993], Liu, Longstaff, and Mandell [2000], Longstaff [2003]).

Hence, the behavior of bid-ask spreads for on-the-run and off-the-run securities deserve special attention. Moreover, Cornell [1993] documents -even during a squeeze- trading volume has a greater impact on bid-ask spreads than a possible adverse selection problem. Therefore, it can be hypothesized that both on-the-run and off-the-run securities are expected to have relatively narrow bid-ask spreads at the beginning of an auction cycle due to the high trading volume of both securities, whereas the bid-ask spread of off-the-run securities are expected to widen later on in the cycle compared to the on-the-run securities' bid-ask spreads. To investigate this issue further, Tables 2-7 through 2-12 present the average bid-ask spreads for on-the-run and off-the-run Treasury bills (13-week and 26-week bills), Treasury notes (2-year, 5-year, and 10-year notes) and 30-year bonds. In addition, these tables break the data period into two sub-periods for pre- and after August 1981, the date when-issued trading was officially sanctioned (Possible effects of this event on the yield spread will be examined by the regression analysis in the following section). Confirming Cornell [1993], for all maturities the difference in bid-ask spreads are not significantly different from each other for on-the-run vs. off-the-run Treasury securities at the beginning of the auction cycles. However, while on-the-run securities maintain a narrow bid-ask spread throughout the auction cycle (as expected due to their popularity throughout the auction cycle), off-the-run securities observe an increasing bid-ask spread towards the end of the auction cycle. In addition, this pattern has higher significance for Treasury bills and 30-year bonds (most liquid securities), and for 1981-1999 sub-period (after the when-issued trading started) relative to 1975-1981 sub-period. This can be explained by the fact that the on-the-run issue enjoys a higher demand and trading volume (due to either one of the documented three reasons), and the

off-the-run issue observes a high trading volume at the beginning of the auction cycle due to the investors who are selling those securities in order to switch to the more liquid on-the-run security. Longstaff [2003] quotes a part of Alan Greenspan's speech from October 7^{th}, 1998, which supports this view:

"But what is crucial about this distinction is that the individuals who were moving from, let's assume, the illiquid US Treasuries to the liquid on-the-run issues, are basically saying, "I want out. I don't want to know anything about whether a particular investment is risky or not. I just want to disengage." And the reason you go into these liquid instruments is that that is the vehicle which enables one to disengage as quickly as possible."

Yield Spread and Some Explanatory Variables

The following part of the analysis presents the results of OLS regressions of the on-the-run vs. off-the- run Treasury yield spreads on some explanatory variables based on the previously hypothesized relationships. The general form of the regression model is:

$$Spread_t = \alpha + \beta_1\ Spread_{t-1} + \beta_2\ (B\text{-}A)S_t + \beta_3\ \Delta MMMF_t + \beta_4\ RS_t + \beta_5\ AUCDUM + \beta_6\ POST81 + e_t$$

where $Spread_t$ is the average on-the-run vs. off-the-run Treasury yield spread for the corresponding auction cycle (weekly, monthly or quarterly),

$Spread_{t-1}$ is the lagged yield spread, average yield spread between off-the-run and on-the-run Treasury securities from previous auction cycle to control for serial correlation,

(B-A)S is bid-ask spread difference, average difference between bid-ask spreads of the off-the-run and on-the-run Treasury securities for the auction cycle,

ΔMMMF is the percentage change in the amount of funds held in money market mutual funds, to capture any effects of flow of funds into the money markets on the demand for liquidity (Longstaff [2003]),

RS is the relative supply, ratio of the amount auctioned for the on-the-run issue to the amount auctioned for the off-the-run issue,

AUCDUM is an auction dummy, equals to unity if the auction was a single-priced Dutch auction, to zero otherwise,

POST81 is a post-August 1981 dummy, equals to unity if auction cycle is after August of 1981 (date when-issued trading was officially sanctioned), to zero otherwise.

Table 2-13 reports the results of the OLS regressions for Treasury securities with different maturities. Lagged yield spread appears to be significant for all securities confirming serial correlation in the yield spread between on-the-run and off-the-run Treasury securities. Another significant coefficient throughout all maturities is the bid-ask spread which was used as a proxy for demand for liquidity in Treasury securities market. All coefficients are positive and significant at 1% level confirming the hypothesis that high yield spreads would be associated with high bid-ask spread differentials (indicating higher demand and trading volume for the on-the-run issue, Cornell [1993]).

Changes in money market mutual fund holdings appear significant only at 10% level and only for Treasury bills and 30-year bonds. However, all coefficients are positive

indicating that flow of funds to money market mutual funds proxy for investors' demand for short-term liquid and safe securities.

Warga [1992], Friedman and Kuttner [1993], Krishnamurthy [2002], and Longstaff [2003] provide evidence for the effect of the supply on liquidity in Treasury securities market. Relative supply variables have negative coefficients as expected (higher supply of the on-the-run issue resulting lower chance of scarcity of that security) and higher significance –again- for Treasury bills and 30-year bonds.

Auction dummy appears to be insignificant implying that our data does not reject the hypothesis that the Treasury's decision to switch from discriminatory to Dutch auctions played no important role in determining the on-the-run vs. off-the-run Treasury yield spread.

Finally, the dummy variable for pre- and post-when-issued trading has significantly positive coefficients for the more liquid securities while having positive values throughout, which confirms earlier findings about the bid-ask spread differentials for these two sub-periods.

Last two rows in Table 2-13 present the number of observations for each regression and R-squared values.

As a robustness check, I experimented with the same model for 1986-1999 period by substituting demand for liquidity variable (previously bid-ask spread) with CP-TBill spread by borrowing the methodology to control for default risk premium in CP-Tbill spread from Krishnamurthy [2002]. First, I ran the regression of daily CP-Tbill spread on AAA-BAA spread, and then used the error terms in the on-the-run vs. off-the-run yield

spread regression, i.e. the new proxy for demand for liquidity is the error term from the following regression:

$(CP\text{-}TBill)_t = \alpha + \beta\,(AAA\text{-}BAA)_t + e_t$

However, data for AAA-BAA spread is only available back to 1986 at Treasury's webpage. Hence, this regression is run for the 1986-1999 period. Table 2-14 reports the results of the analysis with the new measure for demand for liquidity, and its coefficient estimates are also all positive, and have a consistent high significance level throughout different securities. Moreover, substitution of this variable did not change the results presented in Table 2-13. These results indicate that the demand for liquidity plays an important role in on-the-run vs. off-the-run Treasury spread, and using bid-ask spread differential as a proxy for demand for liquidity works as well as the methodology of earlier studies.

Conclusion and Implications for Further Research

This study confirms some of the results of earlier empirical work, i.e. the spread between on-the-run and off-the-run Treasury securities starts at a maximum at the beginning of the auction cycle and it converges to zero towards the end of the cycle. But more importantly, this study's contribution is that it expands the evidence for much longer data sample period and a broad set of Treasury securities available to investors by using a different approach to how to measure for demand for liquidity in the Treasury securities market.. In addition, this study highlights the effect of relative supply and liquidity demand on the yield spread between on-the-run and off-the-run Treasury securities.

In order to better hypothesize the relationships between the yield spread between on-the-run and off-the-run Treasury securities, we need more comprehensive theoretical models that will include not only preceding trading of the securities before issuance, but also trading in both secondary and repo markets after the issuance.

Table 2-1. 13-Week T-Bill On-the-run vs. Off-the-run Yield Spread

Year	Thu	Fri	Mon	Tue	Wed	K-W Test (H_0: All averages are equal)
75-99	9.07 (4.66)*** (7.03)***	4.71 (3.27)*** (3.41)***	2.27 (3.08)*** (2.33)**	1.31 (2.86)*** (1.98)**	0.87 (2.28)** (1.52)*	19.78*** (vs.3.48)
75	8.83 (3.06)*** (5.27)***	4.74 (2.96)*** (3.13)***	1.97 (2.30)** (1.92)**	1.31 (2.33)** (1.59)*	0.86 (2.09)** (1.39)*	16.12***
76	8.99 (3.13)*** (5.36)***	4.85 (3.09)*** (3.22)***	2.01 (3.11)*** (2.26)**	1.27 (2.88)*** (2.00)**	0.83 (2.30)** (1.45)*	16.96***
77	9.25 (3.21)*** (5.39)***	4.87 (3.00)*** (3.16)***	2.02 (2.94)*** (2.28)**	1.30 (2.76)*** (1.87)**	0.89 (2.37)** (1.53)*	18.32***
78	9.36 (3.14)*** (5.51)***	4.87 (3.00)*** (3.02)***	2.06 (3.22)*** (2.28)**	1.29 (2.96)*** (2.09)**	0.84 (2.19)** (1.53)*	16.60***
79	9.67 (3.30)*** (5.24)***	5.02 (3.28)*** (3.43)***	2.23 (3.12)*** (2.17)**	1.35 (2.88)*** (2.01)**	0.93 (2.31)** (1.55)*	20.43***
80	9.64 (3.81)*** (5.66)***	4.98 (3.19)*** (3.30)***	2.21 (3.07)*** (2.22)**	1.31 (2.85)*** (1.97)**	0.91 (2.37)** (1.62)*	19.61***
81	10.09 (4.03)*** (5.93)***	5.10 (3.35)*** (3.52)***	2.34 (3.02)*** (2.36)**	1.39 (2.82)*** (1.93)**	0.94 (2.33)** (1.59)*	15.95***
82	10.26 (3.76)*** (5.82)***	5.13 (3.29)*** (3.44)***	2.37 (3.28)*** (2.14)**	1.42 (3.00)*** (2.14)**	0.96 (2.24)** (1.47)*	16.26***
83	10.31 (4.57)*** (6.38)***	5.16 (3.27)*** (3.40)***	2.44 (3.23)*** (2.19)**	1.38 (2.96)*** (2.10)**	0.94 (2.20)** (1.43)*	18.20***
84	9.18 (4.93)*** (6.88)***	5.01 (3.24)*** (3.36)***	2.28 (3.19)*** (2.24)**	1.35 (2.93)*** (2.07)**	0.91 (2.37)** (1.50)*	17.38***
85	8.82 (4.80)*** (6.47)***	4.70 (3.38)*** (3.57)***	2.31 (2.93)*** (2.27)**	1.24 (2.76)*** (1.86)**	0.80 (2.36)** (1.53)*	18.25***
86	8.94 (4.67)*** (6.99)***	4.77 (3.35)*** (3.53)***	2.26 (3.25)*** (2.31)**	1.17 (2.98)*** (2.12)**	0.73 (2.22)** (1.45)*	16.04***
87	7.71 (4.43)*** (6.76)***	4.52 (3.33)*** (3.50)***	2.24 (3.17)*** (2.32)**	1.26 (2.92)*** (2.05)**	0.82 (2.35)** (1.59)*	15.70***
88	7.58 (4.58)*** (6.96)***	4.28 (3.19)*** (3.29)***	2.21 (3.09)*** (2.24)**	1.21 (2.86)*** (1.48)**	0.77 (2.38)** (1.63)*	17.62***

Table 2-1. (cont.'ed)

89	7.66 (4.71)*** (7.12)***	4.31 (3.37)*** (3.55)***	2.18 (3.00)*** (2.34)**	1.29 (2.30)** (1.41)**	0.85 (2.21)** (1.57)*	18.07***
90	7.64 (5.03)*** (7.08)***	4.24 (3.32)*** (3.48)***	2.21 (2.73)*** (2.06)**	1.23 (2.42)*** (1.50)*	0.79 (2.20)** (1.39)*	18.10***
91	8.78 (5.11)*** (7.14)***	4.77 (3.27)*** (3.41)***	2.29 (2.87)*** (2.20)**	1.35 (2.71)*** (1.81)**	0.91 (2.31)** (1.48)*	19.52***
92	9.07 (5.16)*** (7.27)***	4.88 (3.22)*** (3.34)***	2.34 (3.03)*** (2.37)**	1.44 (2.82)*** (1.93)**	1.00 (2.23)** (1.59)*	19.89***
93	9.76 (4.93)*** (7.06)***	4.97 (3.07)*** (3.13)***	2.32 (2.91)*** (2.25)**	1.41 (2.74)*** (1.84)**	0.97 (2.34)** (1.51)*	20.08***
94	10.27 (4.72)*** (6.99)***	4.92 (3.15)*** (3.24)***	2.48 (2.93)*** (2.27)**	1.37 (2.75)*** (1.85)**	0.93 (2.35)** (1.52)*	20.97***
95	10.04 (5.01)*** (7.12)***	4.84 (3.24)*** (3.36)***	2.41 (3.44)*** (2.32)**	1.34 (3.11)*** (2.28)**	0.90 (2.38)** (1.88)**	20.06***
96	10.34 (4.76)*** (6.89)***	5.01 (3.18)*** (3.27)***	2.63 (3.06)*** (2.21)**	1.43 (2.84)*** (1.96)**	0.99 (2.36)** (1.61)*	22.96***
97	10.47 (4.83)*** (7.21)***	5.07 (3.18)*** (3.28)***	2.66 (2.89)*** (2.23)**	1.46 (2.23)*** (1.53)**	1.02 (2.33)** (1.50)*	22.75***
98	7.07 (5.20)*** (6.93)***	3.28 (3.47)*** (3.71)***	2.14 (2.67)** (1.99)**	1.11 (2.37)** (1.64)*	0.67 (2.14)** (1.34)*	15.59***
99	6.96 (4.73)*** (7.17)***	3.39 (3.26)*** (3.39)***	2.16 (2.70)** (2.03)**	1.17 (2.30)** (1.57)*	0.73 (2.17)** (1.37)*	15.37***

The numbers in the first row of each cell are the average daily spread levels shown in basis points. The second rows present the t-statistics for the null hypothesis that the average spread is zero. Finally, the third rows present Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series.

Table 2-2. 26-Week T-Bill On-the-run vs. Off-the-run Yield Spread

Year	Thu	Fri	Mon	Tue	Wed	K-W Test (H_0: All averages are equal)
75-99	8.94 (4.48)*** (6.81)***	7.38 (3.21)*** (4.11)***	4.44 (3.03)*** (2.12)**	2.15 (2.66)*** (2.03)**	1.12 (2.11)** (1.41)*	16.26*** (vs.3.48)
75	8.85 (4.44)*** (6.86)***	7.31 (3.11)*** (4.11)***	3.89 (3.04)*** (2.13)**	1.99 (2.69)*** (1.96)**	0.89 (2.11)** (1.42)*	13.33***
76	9.01 (4.30)*** (7.01)***	7.48 (3.09)*** (4.06)***	4.09 (3.25)*** (2.01)**	2.03 (2.79)*** (1.94)**	0.99 (2.06)** (1.28)	13.78***
77	9.18 (4.51)*** (6.88)***	7.54 (3.28)*** (3.96)***	4.15 (2.99)*** (2.16)**	2.02 (2.71)*** (2.08)**	0.97 (1.97)** (1.46)*	15.40***
78	9.34 (4.66)*** (6.65)***	7.75 (3.36)*** (4.24)***	4.39 (3.07)*** (2.12)**	2.10 (2.55)*** (2.14)**	1.05 (2.23)** (1.41)*	14.22***
79	9.51 (4.65)*** (6.47)***	7.84 (3.28)*** (4.44)***	4.48 (3.09)*** (1.95)**	2.09 (2.44)*** (2.08)**	1.06 (2.42)** (1.21)	16.68***
80	9.72 (4.72)*** (6.67)***	7.98 (3.42)*** (4.03)***	4.62 (3.10)*** (2.06)**	2.12 (2.57)*** (2.18)**	1.09 (2.04)** (1.34)*	15.98***
81	9.74 (4.17)*** (6.75)***	8.05 (3.13)*** (3.95)***	4.73 (3.01)*** (2.19)**	2.09 (2.62)*** (1.97)**	1.11 (1.96)** (1.49)*	13.26***
82	10.08 (4.45)*** (6.83)***	8.28 (3.16)*** (4.11)***	4.96 (3.08)*** (2.07)**	2.18 (2.67)*** (1.99)**	1.18 (2.11)** (1.35)*	16.01***
83	10.16 (4.63)*** (6.60)***	8.33 (3.20)*** (3.92)***	5.01 (3.11)*** (2.13)**	2.29 (2.52)*** (2.02)**	1.23 (1.93)** (1.42)*	16.45***
84	9.03 (4.33)*** (6.66)***	7.19 (3.36)*** (4.29)***	4.86 (2.93)*** (2.02)**	2.13 (2.56)*** (2.14)**	1.20 (2.28)** (1.29)*	15.86***
85	8.67 (4.38)*** (6.39)***	6.51 (3.11)*** (3.97)***	4.55 (3.10)*** (1.98)**	2.16 (2.39)** (1.96)**	1.09 (1.98)** (1.25)	14.38***
86	8.79 (4.24)*** (6.94)***	6.62 (3.09)*** (3.98)***	4.62 (3.05)*** (2.16)**	2.11 (2.75)*** (1.94)**	1.02 (1.99)** (1.46)*	13.21***
87	7.56 (4.22)*** (6.46)***	6.31 (3.26)*** (4.06)***	4.37 (3.17)*** (2.27)**	2.09 (2.43)*** (2.07)**	1.11 (2.06)** (1.59)*	12.89***
88	7.43 (4.34)*** (6.67)***	6.19 (3.20)*** (4.28)***	4.13 (2.87)*** (2.11)**	2.06 (2.57)*** (2.02)**	1.06 (2.27)** (1.40)*	15.88***

Table 2-2. (cont.'ed)

89	7.51 (4.37)*** (6.90)***	6.22 (3.13)*** (4.03)***	4.16 (2.85)*** (1.97)**	2.03 (2.72)*** (1.97)**	1.14 (2.04)** (1.23)	14.36***
90	7.49 (4.18)*** (6.79)***	6.19 (3.20)*** (4.29)***	4.09 (3.01)*** (2.24)**	2.06 (2.65)*** (2.02)**	1.08 (2.28)** (1.55)*	15.70***
91	8.63 (4.40)*** (6.96)***	7.28 (3.24)*** (4.35)***	4.62 (3.12)*** (2.46)**	2.14 (2.75)*** (2.05)**	1.20 (2.33)** (1.81)**	16.55***
92	8.92 (4.42)*** (6.80)***	8.19 (3.44)*** (4.22)***	4.73 (2.98)*** (2.28)**	2.19 (2.65)*** (2.20)**	1.29 (2.21)** (1.60)*	16.38***
93	9.61 (4.50)*** (6.64)***	8.22 (3.19)*** (4.19)***	4.82 (2.95)*** (2.07)**	2.17 (2.55)*** (2.02)**	1.26 (2.19)** (1.35)*	17.21***
94	10.12 (4.43)*** (6.92)***	8.16 (3.41)*** (3.89)***	4.77 (3.22)*** (2.10)**	2.33 (2.73)*** (2.18)**	1.22 (1.91)** (1.39)*	17.64***
95	9.89 (4.43)*** (6.72)***	8.03 (3.33)*** (4.26)***	4.69 (3.12)*** (2.05)**	2.26 (2.60)*** (2.12)**	1.19 (2.25)** (1.33)*	17.75***
96	10.19 (4.39)*** (6.84)***	8.29 (3.01)*** (4.12)***	4.86 (2.94)*** (2.13)**	2.48 (2.68)*** (1.88)**	1.28 (2.12)** (1.42)*	18.01***
97	10.32 (4.67)*** (7.00)***	8.32 (3.34)*** (3.96)***	4.92 (3.15)*** (2.25)**	2.51 (2.79)*** (2.12)**	1.31 (1.97)** (1.56)*	16.91***
98	6.92 (4.47)*** (6.61)***	6.01 (2.91)*** (4.07)***	3.13 (3.01)*** (2.14)**	1.99 (2.53)** (1.81)**	0.96 (2.07)** (1.44)*	12.06***
99	6.81 (4.45)*** (6.39)***	6.12 (3.00)*** (3.97)***	3.24 (3.10)*** (2.12)**	2.01 (2.39)** (1.88)**	1.02 (1.98)** (1.41)*	12.36***

The numbers in the first row of each cell are the average daily spread levels shown in basis points. The second rows present the t-statistics for the null hypothesis that the average spread is zero. Finally, the third rows present Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series.

Table 2-3. 2-Year T-Note On-the-run vs. Off-the-run Yield Spread

Period	Week 1	Week 2	Week 3	Week 4
75-99 **K-W Test** **(H_0: All averages are equal)** 11.07*** (vs. 3.95)	7.50 (3.67)*** (6.56)***	5.39 (3.09)*** (2.29)**	2.44 (2.41)*** (2.03)**	1.17 (2.23)** (1.39)*
1975	7.27	4.52	2.46	1.09
1976	7.27	4.64	2.50	1.07
1977	7.32	4.65	2.49	1.09
1978	7.29	4.83	2.37	1.14
1979	7.37	4.83	2.43	1.10
1980	7.31	4.95	2.44	1.11
1981	7.43	4.81	2.46	1.17
1982	7.40	5.28	2.29	1.14
1983	9.03	6.80	2.43	1.19
1984	7.90	5.66	2.54	1.26
1985	7.54	4.98	2.38	1.23
1986	7.66	5.09	2.41	1.12
1987	6.43	4.78	2.36	1.05
1988	6.30	4.66	2.34	1.14
1989	6.38	4.69	2.31	1.09
1990	6.36	4.66	2.28	1.17
1991	7.50	5.75	2.31	1.11
1992	7.79	6.66	2.39	1.23
1993	8.48	6.69	2.44	1.32
1994	8.99	6.63	2.42	1.29
1995	8.76	6.50	2.58	1.25
1996	9.06	6.76	2.51	1.22
1997	9.19	6.79	2.73	1.31
1998	5.79	4.48	2.76	1.34
1999	5.68	4.59	2.24	0.99

The numbers in the first row are: the average daily spread levels shown in basis points, t-statistics for the null hypothesis that the average spread is zero (in parenthesis) and Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series (in parenthesis again). The following rows present the average daily spread levels shown in basis points for individual years.

Table 2-4. 5-Year T-Note On-the-run vs. Off-the-run Yield Spread

Period	Week 1	Week 2	Week 3	Week 4
75-99 **K-W Test** **(H_0: All averages are equal)** 9.66*** (vs.3.95)	6.41 (3.27)*** (6.32)***	4.70 (3.14)*** (2.28)**	1.95 (2.23)** (1.96)**	0.88 (2.17)** (1.56)*
1975	6.16	3.85	1.98	0.80
1976	6.22	3.93	1.96	0.78
1977	6.16	3.81	1.95	0.85
1978	6.28	3.89	1.99	0.80
1979	6.15	3.96	1.90	0.85
1980	6.37	4.04	1.97	0.81
1981	6.09	4.12	1.92	0.87
1982	6.51	5.39	1.95	0.85
1983	7.94	6.11	1.94	0.90
1984	6.81	4.97	2.05	0.97
1985	6.45	4.29	1.89	0.94
1986	6.57	4.40	1.92	0.83
1987	5.34	4.09	1.87	0.76
1988	5.21	3.97	1.85	0.85
1989	5.29	4.00	1.82	0.80
1990	5.27	3.97	1.79	0.88
1991	6.41	5.06	1.82	0.82
1992	6.70	5.97	1.90	0.94
1993	7.39	6.00	1.95	1.03
1994	7.90	5.94	1.93	1.00
1995	7.67	5.81	2.09	0.96
1996	7.97	6.07	2.02	0.93
1997	8.10	6.10	2.24	1.02
1998	4.70	3.79	2.27	1.05
1999	4.59	3.90	1.75	0.70

The numbers in the first row are: the average daily spread levels shown in basis points, t-statistics for the null hypothesis that the average spread is zero (in parenthesis) and Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series (in parenthesis again). The following rows present the average daily spread levels shown in basis points for individual years.

Table 2-5. 10-Year T-Note On-the-run vs. Off-the-run Yield Spread

Period	Month 1	Month 2	Month 3
75-99 **K-W Test** **(H_0: All averages are equal)** 10.62*** (vs. 4.82)	6.46 (3.18)*** (6.43)***	3.52 (2.19)** (1.83)**	2.18 (1.72)** (1.46)*
1975	6.80	3.45	2.00
1976	6.94	3.61	2.01
1977	6.93	3.63	2.07
1978	7.05	3.69	2.07
1979	7.08	3.72	2.11
1980	7.17	3.85	2.15
1981	7.14	3.81	2.12
1982	7.28	3.89	2.16
1983	7.32	4.00	2.22
1984	6.18	3.85	2.33
1985	5.50	3.54	2.17
1986	5.61	3.61	2.20
1987	5.30	3.36	2.15
1988	5.18	3.12	2.13
1989	5.21	3.15	2.10
1990	5.18	3.08	2.07
1991	6.27	3.61	2.10
1992	7.18	3.72	2.18
1993	7.21	3.81	2.23
1994	7.15	3.76	2.21
1995	7.02	3.68	2.37
1996	7.28	3.85	2.30
1997	7.31	3.91	2.52
1998	5.00	2.12	2.55
1999	5.11	2.23	2.03

The numbers in the first row are: the average daily spread levels shown in basis points, t-statistics for the null hypothesis that the average spread is zero (in parenthesis) and Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series (in parenthesis again). The following rows present the average daily spread levels shown in basis points for individual years.

Table 2-6. 30-Year T-Bond On-the-run vs. Off-the-run Yield Spread

Period	Month 1	Month 2	Month 3
75-99 K-W Test (H_0: All averages are equal) 16.21*** (vs. 4.88)	11.16 (4.52)*** (6.78)***	8.55 (3.02)*** (2.86)***	3.20 (1.69)** (1.39)*
1975	9.48	7.89	2.65
1976	9.65	8.02	2.66
1977	10.43	8.24	2.89
1978	10.65	8.26	2.85
1979	10.93	8.64	3.04
1980	11.23	8.64	3.05
1981	11.85	8.89	3.16
1982	12.09	9.03	3.28
1983	12.48	9.16	3.31
1984	11.34	9.01	3.42
1985	10.66	8.70	3.26
1986	10.77	8.77	3.29
1987	10.46	8.52	3.24
1988	10.34	8.28	3.22
1989	10.37	8.31	3.19
1990	10.34	8.24	3.16
1991	11.43	8.77	3.19
1992	12.34	8.88	3.27
1993	12.37	8.97	3.32
1994	12.31	8.92	3.30
1995	12.18	8.84	3.46
1996	12.44	9.01	3.39
1997	12.47	9.07	3.61
1998	10.16	7.28	3.64
1999	10.27	7.39	3.12

The numbers in the first row are: the average daily spread levels shown in basis points, t-statistics for the null hypothesis that the average spread is zero (in parenthesis) and Wilcoxon signed rank test statistics for the same null hypothesis to avoid spurious test statistics driven possibly by a few large outliers in the data series (in parenthesis again). The following rows present the average daily spread levels shown in basis points for individual years.

Table 2-7. 13-Week T-Bill Bid-Ask Spread

1975-1999			Wilcoxon Signed Rank Test
	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
Thu	0.0245	0.0276	1.06
Fri	0.0284	0.0353	2.09**
Mon	0.0304	0.0543	3.05***
Tue	0.0311	0.0619	4.27***
Wed	0.0311	0.0616	4.31***
1975-1981			Wilcoxon Signed Rank Test
	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
Thu	0.0251	0.0285	0.87
Fri	0.0293	0.0363	1.31*
Mon	0.0309	0.0567	1.89**
Tue	0.0314	0.0629	3.16***
Wed	0.0315	0.0627	3.68***
1981-1999			Wilcoxon Signed Rank Test
	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
Thu	0.0239	0.0266	1.10
Fri	0.0274	0.0343	2.13**
Mon	0.0299	0.0519	4.68***
Tue	0.0308	0.0609	4.80***
Wed	0.0306	0.0604	4.79***

Table 2-8. 26-Week T-Bill Bid-Ask Spread

1975-1999			**Wilcoxon Signed Rank Test**
	On-the-Run	**Off-the-Run**	**(H_0: Off ≤On)**
Thu	0.0315	0.0332	0.61
Fri	0.0317	0.0384	1.58*
Mon	0.0319	0.0630	2.09**
Tue	0.0321	0.0630	3.56***
Wed	0.0324	0.0632	4.09***
1975-1981			**Wilcoxon Signed Rank Test**
	On-the-Run	**Off-the-Run**	**(H_0: Off ≤On)**
Thu	0.0318	0.0342	0.57
Fri	0.0319	0.0411	1.29*
Mon	0.0318	0.0641	1.72**
Tue	0.0322	0.0637	2.45***
Wed	0.0325	0.0627	2.59***
1981-1999			**Wilcoxon Signed Rank Test**
	On-the-Run	**Off-the-Run**	**(H_0: Off ≤On)**
Thu	0.0311	0.0322	0.82
Fri	0.0315	0.0357	1.60*
Mon	0.0319	0.0619	2.41***
Tue	0.0320	0.0623	3.78***
Wed	0.0322	0.0636	4.16***

Table 2-9. 2-Year T-Note Bid-Ask Spread

1975-1999			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0588	0.0602	0.42
2	0.0600	0.0626	0.73
3	0.0611	0.0653	1.29*
4	0.0607	0.0900	1.82**
1975-1981			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0604	0.0610	0.51
2	0.0612	0.0634	0.93
3	0.0615	0.0676	1.09
4	0.0609	0.0908	1.99**
1981-1999			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0572	0.0593	0.63
2	0.0587	0.0618	1.08
3	0.0607	0.0629	1.56*
4	0.0605	0.0892	2.27**

Table 2-10. 5-Year T-Note Bid-Ask Spread

1975-1999			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0609	0.0618	0.36
2	0.0620	0.0643	0.68
3	0.0632	0.0669	1.31*
4	0.0628	0.0917	1.93**
1975-1981			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0627	0.0631	0.38
2	0.0635	0.0655	0.77
3	0.0638	0.0697	1.35*
4	0.0632	0.0929	2.01**
1981-1999			Wilcoxon Signed Rank Test
Week	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0590	0.0605	0.47
2	0.0605	0.0630	1.03
3	0.0625	0.0641	1.44*
4	0.0623	0.0904	2.19**

Table 2-11. 10-Year T-Note Bid-Ask Spread

1975-1999			Wilcoxon Signed Rank Test
Month	**On-the-Run**	**Off-the-Run**	**(H_0: Off $\leq$On)**
1	0.0603	0.0624	0.39
2	0.0626	0.0675	1.35*
3	0.0622	0.0922	2.05**
1975-1981			**Wilcoxon Signed Rank Test**
Month	**On-the-Run**	**Off-the-Run**	**(H_0: Off $\leq$On)**
1	0.0620	0.0631	0.46
2	0.0631	0.0697	1.31*
3	0.0625	0.0929	1.78**
1981-1999			**Wilcoxon Signed Rank Test**
Month	**On-the-Run**	**Off-the-Run**	**(H_0: Off $\leq$On)**
1	0.0586	0.0616	0.52
2	0.0621	0.0652	1.59*
3	0.0619	0.0915	2.16**

Table 2-12. 30-Year T-Bond Bid-Ask Spread

1975-1999			Wilcoxon Signed Rank Test
Month	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0658	0.0705	1.06
2	0.0720	0.0998	1.48*
3	0.0714	0.1512	2.41***
1975-1981			Wilcoxon Signed Rank Test
Month	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0671	0.0713	1.01
2	0.0742	0.1003	1.26*
3	0.0735	0.1526	2.28**
1981-1999			Wilcoxon Signed Rank Test
Month	On-the-Run	Off-the-Run	(H_0: Off $\leq$On)
1	0.0644	0.0696	1.11
2	0.0698	0.0993	1.52*
3	0.0692	0.1498	2.69***

Table 2-13. Regression of Yield Spread on Some Explanatory Variables

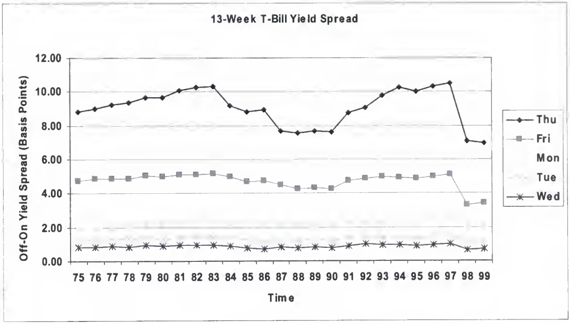
	13-Week T-Bill (Feb1980-1999)	26-Week T-Bill (Feb1980-1999)	2-Year T-Note (1975-1999)	5-Year T-Note (1975-1999)	10-Year T-Note (1975-1999)	30-Year T-Bond (1975-1999)
	(weekly regression)	(weekly regression)	(monthly regression)	(monthly regression)	(quarterly regression)	(quarterly regression)
INTRCPT	2.21 (3.38)***	2.06 (3.21)***	1.40 (2.10)**	1.17 (2.16)**	1.69 (2.49)**	2.03 (3.36)***
$Spread_{t-1}$	4.04 (5.36)***	4.10 (5.41)***	3.47 (4.06)***	3.68 (4.35)***	3.20 (4.21)***	4.51 (6.78)***
(B-A)S	2.21 (6.69)***	1.97 (6.42)***	1.10 (5.10)***	1.08 (5.06)***	1.43 (4.48)***	2.62 (7.21)***
ΔMMMF	0.76 (1.78)*	0.83 (1.83)*	0.46 (1.21)	0.39 (1.36)	0.53 (1.59)	0.79 (1.90)*
RS	-1.16 (-2.66)***	-1.10 (-2.75)***	-0.82 (-1.73)*	-0.93 (-1.68)*	-0.68 (-1.82)*	-1.41 (-2.03)**
AUCDUM	0.68 (1.34)	0.73 (1.42)	0.48 (0.98)	0.27 (0.72)	0.31 (1.31)	0.76 (1.27)
POST81	1.04 (2.21)**	0.94 (2.19)**	0.72 (1.59)	0.66 (1.48)	0.69 (1.61)	1.32 (2.36)**
N	1,035	1,027	296	286	97	87
R^2 (%)	34.27	32.96	58.43	56.76	52.50	76.01

* The dependent variable is the average off-the-run minus on-the-run Treasury security yield spread for the corresponding auction cycle (i.e., weekly, monthly, or quarterly).
* $Spread_{t-1}$: Lagged Yield Spread, average yield spread between off-the-run and on-the-run Treasury securities from previous auction cycle.
* (B-A)S: Bid-Ask Spread Difference, average difference between bid-ask spreads of the off-the-run and on-the-run Treasury securities for the auction cycle.
* ΔMMMF: Percentage change in the amount of funds held in money market mutual funds.
* RS: Relative Supply, ratio of the amount auctioned for the on-the-run issue to the amount auctioned for the off-the-run issue.
* AUCDUM: Auction Dummy, equals to unity if the auction was a single-priced Dutch auction, to zero otherwise.
* POST81: Post August 1981 Dummy, equals to unity if auction cycle is after August of 1981 (date when-issued trading was officially sanctioned), to zero otherwise.
* Numbers in parentheses are two-tailed t-statistics. *, **, *** represent significance at 10, 5, and 1% level, respectively.

Table 2-14. Regression of Yield Spread (with a different liquidity variable)

	13-Week T-Bill (1986-1999)	**26-Week T-Bill (1986-1999)**	**2-Year T-Note (1986-1999)**	**5-Year T-Note (1986-1999)**	**10-Year T-Note (1986-1999)**	**30-Year T-Bond (1986-1999)**
	(weekly regression)	(weekly regression)	(monthly regression)	(monthly regression)	(quarterly regression)	(quarterly regression)
INTRCPT	1.43 (3.29)***	1.38 (3.06)***	1.32 (2.03)**	1.09 (2.19)**	1.73 (2.38)**	2.11 (3.41)***
$Spread_{t-1}$	4.13 (4.74)***	4.09 (5.36)***	3.01 (3.76)***	3.55 (4.13)***	3.11 (4.00)***	4.63 (5.41)***
CP-Tbill	3.48 (5.73)***	3.55 (5.39)***	3.06 (4.80)***	3.21 (4.92)***	3.56 (4.69)***	3.40 (5.46)***
ΔMMMF	0.81 (1.66)*	0.96 (1.82)*	0.53 (1.34)	0.42 (1.29)	0.58 (1.61)	0.83 (1.93)*
RS	-1.31 (-2.73)***	-1.03 (-2.59)***	-0.94 (-1.75)*	-1.00 (-1.72)*	-0.81 (-1.91)*	-1.56 (-2.10)**
AUCDUM	0.73 (1.21)	0.66 (1.30)	0.51 (0.76)	0.42 (0.81)	0.43 (1.08)	0.63 (1.30)
POST81	1.14 (2.06)**	1.06 (2.10)**	0.81 (1.50)	0.70 (1.57)	0.83 (1.56)	1.29 (2.41)**
N	728	726	168	156	56	43
R^2 (%)	33.06	30.01	56.29	55.51	52.38	76.45

* The dependent variable is the average off-the-run minus on-the-run Treasury security yield spread for the corresponding auction cycle (i.e., weekly, monthly, or quarterly).
* $Spread_{t-1}$: Lagged Yield Spread, average yield spread between off-the-run and on-the-run Treasury securities from previous auction cycle.
* CP-TBill: Error terms of the regression of CP-TBill spread on AAA-BAA spread, as a proxy for demand for liquidity (Krishnamurthy [2002]),
* ΔMMMF: Percentage change in the amount of funds held in money market mutual funds.
* RS: Relative Supply, ratio of the amount auctioned for the on-the-run issue to the amount auctioned for the off-the-run issue.
* AUCDUM: Auction Dummy, equals to unity if the auction was a single-priced Dutch auction, to zero otherwise.
* POST81: Post August 1981 Dummy, equals to unity if auction cycle is after August of 1981 (date when-issued trading was officially sanctioned), to zero otherwise.
* Numbers in parentheses are two-tailed t-statistics. *, **, *** represent significance at 10, 5, and 1% level, respectively.


13-Week T-Bill Yield Spread
Off-On Yield Spread (Basis Points)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Thu
Fri
Mon
Tue
Wed

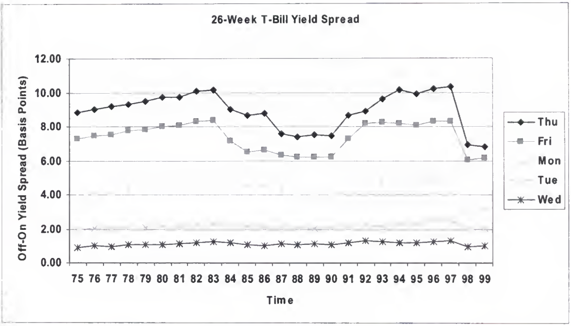
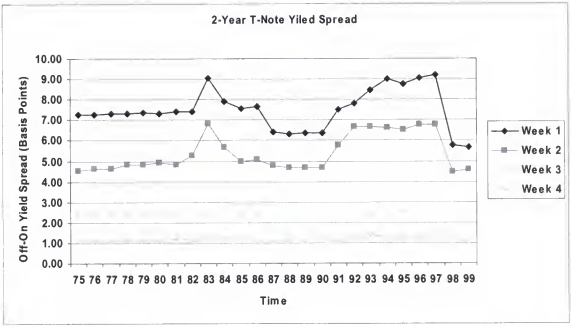

26-Week T-Bill Yield Spread
Off-On Yield Spread (Basis Points)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Thu
Fri
Mon
Tue
Wed

Figure 2-1.


2-Year T-Note Yiled Spread
Off-On Yield Spread (Basis Points)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Week 1
Week 2
Week 3
Week 4

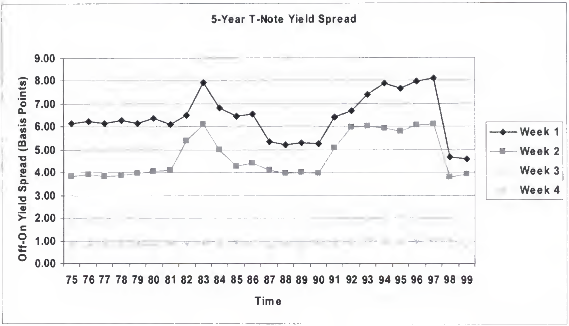
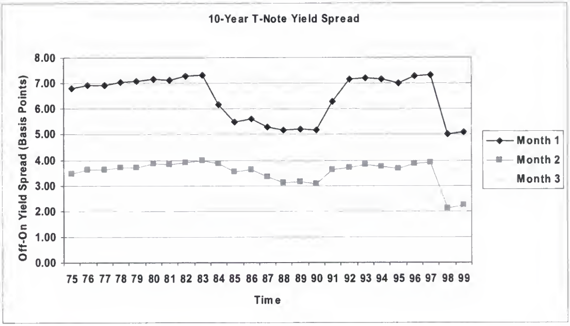

5-Year T-Note Yield Spread
Off-On Yield Spread (Basis Points)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Week 1
Week 2
Week 3
Week 4

Figure 2-2.


10-Year T-Note Yield Spread
Off-On Yield Spread (Basis Points)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Month 1
Month 2
Month 3

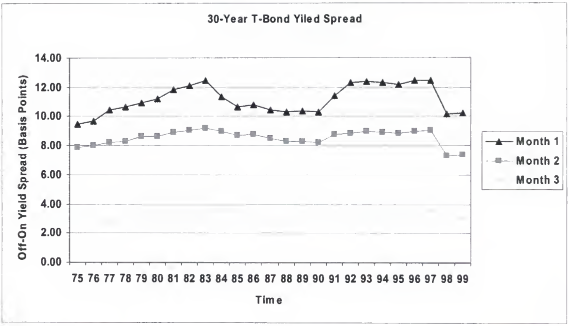

30-Year T-Bond Yiled Spread
Off-On Yield Spread (Basis Points)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Time
Month 1
Month 2
Month 3

Figure 2-3.

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BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to the acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mark J. Flannery, Chairman
Bank of America Eminent Scholar of
Finance, Insurance and Real Estate

I certify that I have read this study and that in my opinion it conforms to the acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Andy Naranjo
Associate Professor of Finance, Insurance
and Real Estate

I certify that I have read this study and that in my opinion it conforms to the acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Estate

I certify that I have read this study and that in my opinion it conforms to the acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the Department of Finance, Insurance and Real Estate in the College of Business Administration and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 2004

Dean, Graduate School